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FLOW MEASUREMENT BY PULSED-NEUTRON ACTIVATION TECHNIQUES AT THE PKL FACILITY AT ERLANGEN (GERMANY)

by

Paul Kehler

Prepared for the

Office of Nuclear Regulatory Research
U. S. NUCLEAR REGULATORY COMMISSION
under Interagency Agreement DOE 40-550-75

129

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ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

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by

Paul Kehler

Components Technology Division

March 1982

Prepared for the Division of Accident Evaluation
Office of Nuclear Regulatory Research
U. S. Nuclear Regulatory Commission
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ABSTRACT

Flow velocities in the downcomer at the PKL facility (in Erlangen, Germany) were measured by the Pulsed-Neutron Activation (PNA) technique. This was the first time that a fully automated PNA system, incorporating a dedicated computer for on-line data reduction, was used for flow measurements. A prototype of a portable, pulsed, high-output neutron source, developed by the Sandia National Laboratories for the U.S. Nuclear Regulatory Commission, was also successfully demonstrated during this test. The PNA system was the primary flow-measuring device used at the PKL, covering the whole range of velocities of interest. In this test series, the PKL simulated small-break accidents similar to the one that occurred at TMI. The flow velocities in the downcomer were, therefore, very low, ranging between 0.03 and 0.35 m/sec.

Two additional flow-measuring methods were used over a smaller range of velocities. Wherever comparison was possible, the PNA-derived velocity values agreed well with the measurements performed by the two more conventional methods.

NRC FIN No.	Title
A2052	Flow Measurement by Pulsed-Neutron Activation Techniques at the PKL Facility

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The experimental work described in this report was performed at the PKL facility at Erlangen, Germany. The whole staff running the PKL has cooperated enthusiastically with the U.S. participants in this test (myself and G. Rochau from the Sandia National Laboratories) and has responded to even the slightest of our needs and wishes. To them all go my thanks, but I am particularly grateful to H. Gaul, B. Brand, and D. Hein.

NOMENCLATURE

NOMENCLATURE

$A(t)$	=	Activity of the fluid passing detector at time t(Ci)
A_o	=	Total activity (Ci)
A_1	=	Activity at a first detector (Ci)
A_2	=	Activity at a second detector (Ci)
B	=	Total number of background counts (counts)
b	=	Background (counts/channel)
b_o	=	Constant background (counts/channel)
b_a	=	Decaying background (counts/channel)
C(t)	=	Decay-corrected number of counts per channel
c(t)	=	Number of counts per channel
C_1	=	Sensitivities of a first detector (counts/Ci)
C_2	=	Sensitivity of the detector (counts/Ci)
d	=	Distance from source/detector (cm)
N	=	Number of counts registers by the detector
n	=	Time exponent in velocity equation
r	=	Distance from centerline of pipe (cm)
S	=	Source strength (neutrons/pulse)
T	=	Transit time between source and detector (s)
$\bar{T}$	=	Average transit time (s)
t	=	Time after irradiation of the fluid (s)
t_o	=	The mode of the count-time distribution (s)
t'	=	Median of the count-time distribution (s)
$\bar{t}$	=	Mean of the count-time distribution (s)
U	=	Flow velocity (cm/s)
U_D	=	Flow velocity at the detector (cm/s)
U_M	=	Average mass-flow velocity (cm/s)
U_T	=	Transit-time velocity (cm/s)
Z	=	Coordinate along centerline of pipe (cm)
Z_0	=	Distance between source and detector (cm)
Z_D	=	Distance between two detectors (cm)
dZ	=	Source "window" or collimation (cm)
ΔT	=	Residence time of activity A(t) in the window ΔZ
ΔZ	=	Detector "window" or collimation(cm)
λ	=	Decay constant of N^{16} (s^{-1})
$\lambda(b)$	=	Decay constant of background (s^{-1})

FLOW MEASUREMENT BY PULSED-NEUTRON ACTIVATION TECHNIQUES AT THE PKL FACILITY AT ERLANGEN (GERMANY)

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Executive Summary

The Pulsed-Neutron Activation (PNA) technique is a special version of tracer techniques commonly used for flow measurements. Distinct features of the PNA technique are that it is not intrusive and that the tracer used for "tagging" of the fluid is produced in situ by activation of the fluid itself. Although known since 1971, this technique has not been widely used because of the nonavailability of small, portable neutron sources of sufficiently high yields. The Argonne National Laboratory, having had available small neutron sources that were developed for other Government programs, has intorduced PNA techniques to the flow measurement in Reactor Safety Research. Methods to measure two-phase mass flow were developed in 1978. Following this demonstration of the potential of PNA techniques, the U.S. Nuclear Regulatory Commission has sponsored the development (at the Sandia National Laboratories) of a pulsed, portable neutron source with a very high output of 10^{10} neutron per pulse. A prototype of this new source was used to measure the flow velocity in the downcomer of the PKL. The new source's performance to NRC specifications was demonstrated in this test. Also demonstrated in this test was the capability of the PNA system to measure flow automatically, i.e., without input by the operator; test data were recorded and evaluated on-line by a dedicated computer.

In the present test, the PKL simulated small-break accidents similar to the one a TMI. The flow velocities in the downcomer were, therefore, very low and ranged between 0.03 and 0.35 m/s. No conventional instruments are capable of measuring such low flows at PKL temperatures. Some measurements were taken by venturi meters, however, and, in addition, the flow was claculated by thermal-balance considerations for some of the test conditions. The primary flow- measuring device, covering the whole velocity range, was the PNA

system. PNA-derived values agreed well with the measurements made by the two other methods, whenever available.

Interpretations (by Kraftwerk-Union, Germany) of data taken in this test led to the conclusion that decay heat can be readily removed from the core by the steam generators' secondary side for conditions of single-phase or two-phase natural circulation, or for heat transfer in the reflux condenser mode. This means that in small-break accidents removal of decay heat from the core is assured as long as coolant (single-or two-phase) is covering the core and as long as heat can be removed from the steam generators' secondary side.

1. INTRODUCTION

After the TMI incident, work at many reactor-simulating test facilities concentrated on the study of effects of small breaks. In small-break tests, the pumps of the primary cooling system are normally shut off and cooling of the core is maintained by natural circulation or by heat transfer in the reflux condenser mode. The coolant's flow velocities through the system are very low in these operating modes. Conventional flowmeters such as turbines, pitot tubes, or venturis are not capable of measuring these slow flows at the operating temperatures of the loops. Pulsed Neutron Activation (PNA) techniques, on the other hand, work best at low flow velocitis and high densities. The present report describes the instrumentation, methods, and test results of the first slow-flow measurement performed by PNA techniques. These measurments were performed at the PKL facility at Erlangen, Germany.

2. PKL FACILITY

The Primaerkreislauf (PKL) facility is operated by the KWU (a subsidiary of Siemens) at Erlangen, Germany. The PKL is a mixed-scale simulation of a 1300-MWe PWR: it has full vertical dimensions but is scaled down horizontally. The core contains 340 electrically heated "fuel bundles" and has a diameter of 52 cm. The downcomer is simulated by a separate pipe, having an ID of 20 cm. Figure 1 is a schematic diagram of the main components of the facility.

The PKL facility was originally designed to examine the refill and reflood phases of a Loss of Coolant Accident (LOCA), but was modified for the present test series to be used for transient and steady-state studies of small breaks.

3. PNA EQUIPMENT

A block diagram of the PNA setup used at the PKL is shown in Fig. 2. A pulsed neutron source is used to activate, or to "tag" instantaneously, the fluid contained in the length dZ of the pipe. This activated slug then moves down the pipe and, when passing through the detector window ΔZ, deposits a certain number of counts in the gamma-ray detector. The measured time-counts distribution is then interpreted in terms of flow velocity, as shown in Section 4. In the present test, the distance Z_o between the source and the detector was 1.0 m.

Fig. 1 Schematic of the PKL

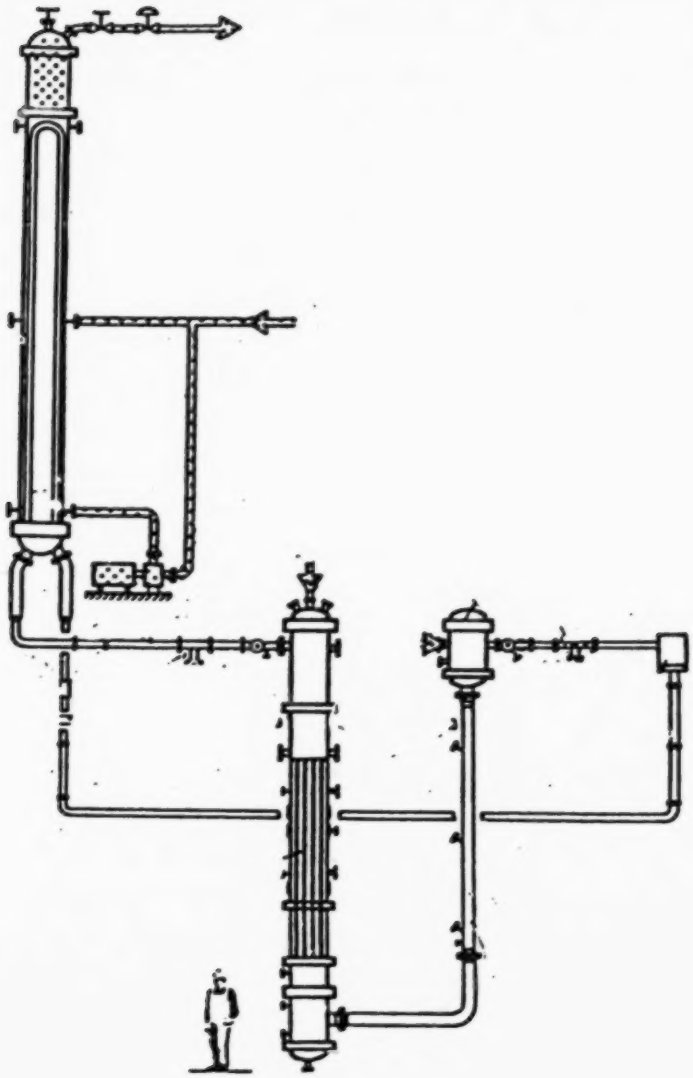
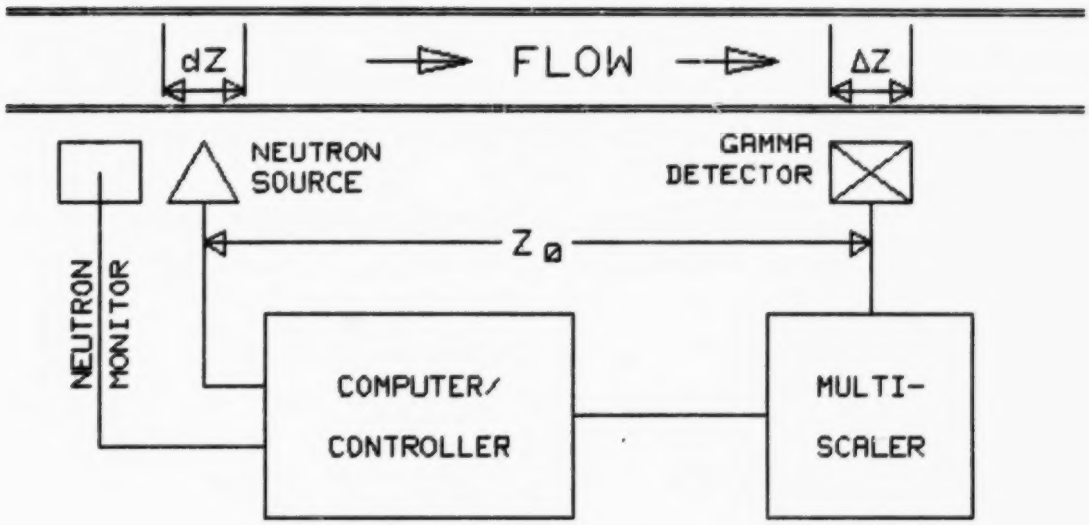


Fig. 2 Block Diagram of PNA Equipment



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The first prototype of pulsed neutron sources specifically developed for PNA work by the Sandia National Laboratories was used in this test. This source worked reliably throughout the whole test at the specified level of 10^{10} neutrons/pulse.

A water-cooled, four-segmented NaI Torus detector was mounted right above a large flange on the downcomer. The detector signals were fed through stabilized amplifiers (locked on the Cs^{137} peak) and discriminators (set at 1 MeV) to a Packard Model 9012 multichannel analyzer, which was operated in its multiscaler mode (256 channels). Test data originally stored in the multichannel analyzer were then retrieved and analyzed by an HP 9845B computer.

A single trigger was used to operate the source, to start the multiscaler, and to furnish an interfacing time signal to the DAS of the PKL.

The individual component of the PNA system are described in more detail below.

3.1 Source

The first prototype of a high-output, pulsed neutron generator that was developed by the Sandia National Laboratories for the USNRC, was used in this test.[1,2] This neutron generator generates $>10^{10}$ 14-MeV D-T neutrons in a 1.2-ms pulse.

The PNA generator has been designed to meet the requirements listed in Table 1. Each operation of the unit will produce a nominal total neutron output of 1.2×10^{10} neutrons. The generator has been designed to be easily repaired and modified. The unit requires no additional equipment for operation or measurement of output.

The generator has a minmal operational life of 1000 pulses and can be pulsed up to 12 pulses/minute for 1 minute. After 1 minute, the neutron output falls below 10^{10}. Pulses every 30 seconds can be repeated continuously. High repetition rates (>6 pulses/minute) can cause damage to the neutron tube and shorten the operational life of the generator. When the end of operational life is reached, the neutron tube will require minor servicing to restore the neutron output.

The PNA neutron generator has been segmented into three major component

Table 1

PNA NEUTRON GENERATOR SPECIFICATIONS

Neutron output:	$>10^{10}$ neutrons/pulse
Pulse duration:	1.2 ms
Pulse repetition rate:	$\leq$ pulses/minute
Lifetime:	$\geq$1000 pulses (low repetition rate)
	$\geq$100 pulses (high repetition rate)
Life-limiting mechanism:	Neutron tube
Exclusive lifetime:	$\geq$10,000 pulses
Neutron monitor:	Integral part of generator
	Sensitive to high neutron fluxes,
	insensitive to experimental geometry.

FEATURES

Repairability:	Completely demountable
Flexibility:	Easily modified
Portability	Two people required
Safety:	Cannot be triggered accidentally
Completeness:	Requires ac line power only
Availability:	Most parts commercially available

assemblies. Each major assembly contains the individual components which are required to operate the generator. These assemblies, interconnected by up to 60-meter cables, allow the experimenter to conveniently place them in the available space of the experimental area. The major assemblies are shown in Fig. 3. The major assemblies, from left to right, are: the Tube-Transformer Assembly (TTA), the Pulse Forming Network (PFN) box, and the control unit.

The generator uses a millisecond pulse (MSP) neutron tube which was specifically developed for this application. This unclassified tube uses a focused deuterium ion beam produced by a specially modified occluded gas ion source. The deuterium beam impinges a 100% tritium-loaded scandium tritide target to produce an isotropic distribution of neutrons with an energy of approximately 14 million electron volts.

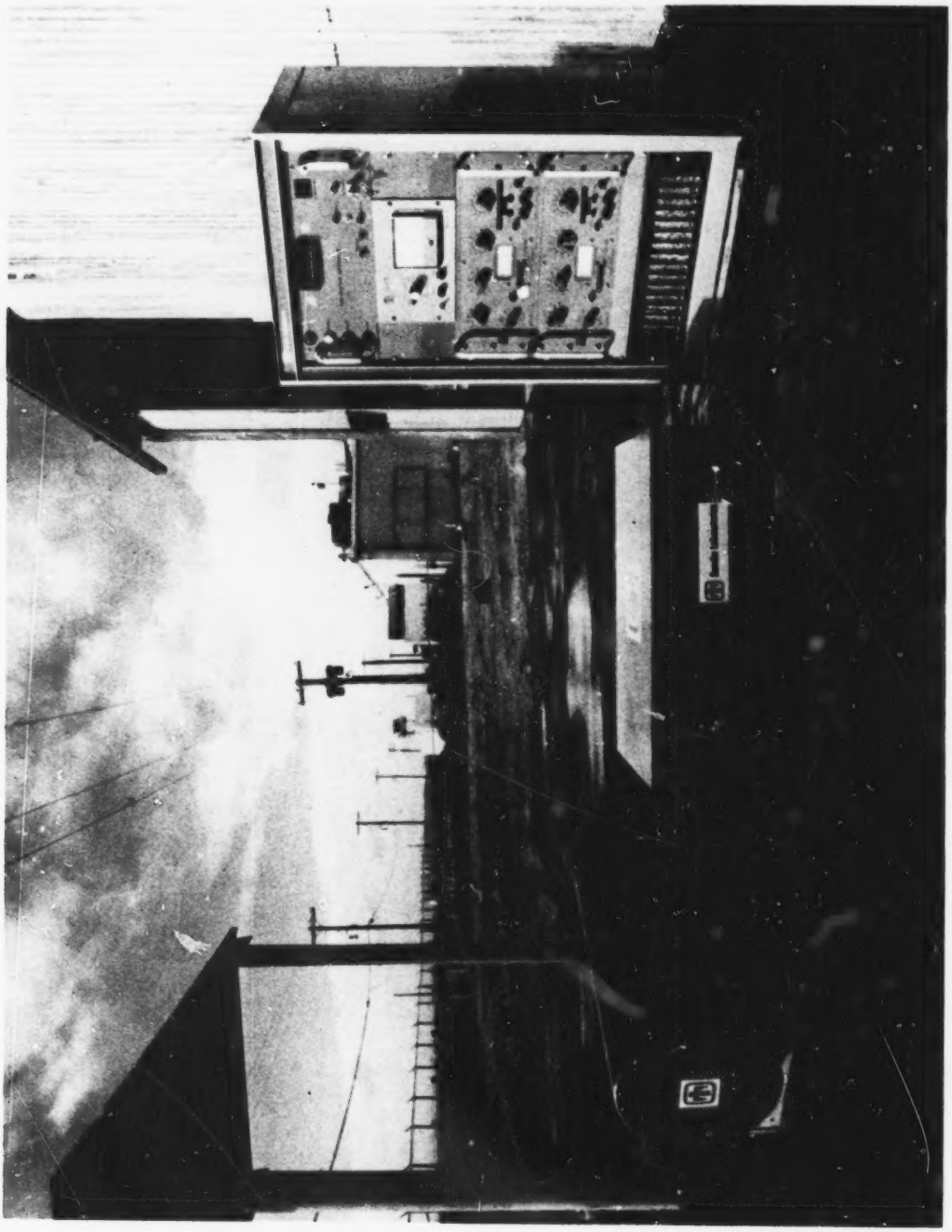
The MSP neutron tube is housed in the TTA which is placed at the position where the source of neutrons is desired. The neutron-producing target is located 5.97 cm behind the front surface of the TTA. The TTA is enclosed in a stainless steel cylinder 32.4 cm in diameter and 66 cm long. The cylinder is pressurized to 345 kPa (50 psi) with sulfur hexafluoride gas to provide high-voltage insulation.

A neutron monitor is mounted 12 cm from the target of the neutron tube, within the TTA assembly. It consists of an unbiased 600-mm^2 silicone photodiode with a 1.14-mm-thick polyethylene proton radiator. The output of the neutron monitor is a voltage proportional to the total number of neutrons generated, and is read by a peak reader which displays the peak voltage on a digital voltmeter on the control panel.

The neutron generator was installed on the downcomer of the PKL test loop at the location indicated in Fig. 1. Biological shielding was required for the generator to reduce radiation exposure to personnel in the area during generator operation. The shield was designed for a minimum thickness of 43 cm of polyethylene around the TTA to keep the dose at 1 meter from the source below 4 rem for 2500 pulses. The TTA was enclosed in a cooling jacket inside the shield to keep the TTA temperature below 38°C.

The PFN box was located 6 from the TTA in an isolated area. The control unit was located 42 m from the TTA location in the control room of the test facility with the other PNA equipment.

Fig. 3 PNA Neutron Generator



3.2 Detector

One of the beneficial characteristics of the PNA flow-measuring techniques described in Section 4 is that its velocity readings are not affected by the various flow regimes but, instead, always give the true mass flow velocity. This is true only, however, as long as the neutron fluence over the whole cross section of the pipe is constant and as long as the detector's sensitivity is constant for all regions of the pipe. These conditions are met to a sufficient degree only in small-diameter pipes. Whenever the pipe diameter exceeds 10 cm, the attenuation of neutrons and gamma rays in the fluid becomes significant. Furthermore, the interaction of the individual pipe regions with the source and the detector decreases with $1/d^2$, where d = the distance from the source or the detector, due to the decrease of the solid angle occupied by the region. Because of these attenuation and geometry effects, fluid regions at larger distances from the source and the detector will contribute less to the total number of counts than regions that are located close to the source and the detector. This non-uniformity of activation and detection can be compensated to some degree by using more than one neutron source (arranged circumferentially around the pipe) and by using a torus detector that completely encircles the pipe.

One such torus detector, with an ID of 15 cm, was available to ANL for this test. The length of this detector is also 15 cm, and its height is 8 cm. It consists of four separate quarter segments that can be water-cooled if necessary, as shown in Fig. 4. The sensitive volume of the detector is NaI scintillating material. Since the diameter of the downcomer of the PKL is 20 cm, the four segments of the detector did not completely cover the circumference of the pipe. Instead, they were mounted at 90-degree intervals around the downcomer, as shown in Fig. 5.

Fig. 4 Segments of Torus Detector

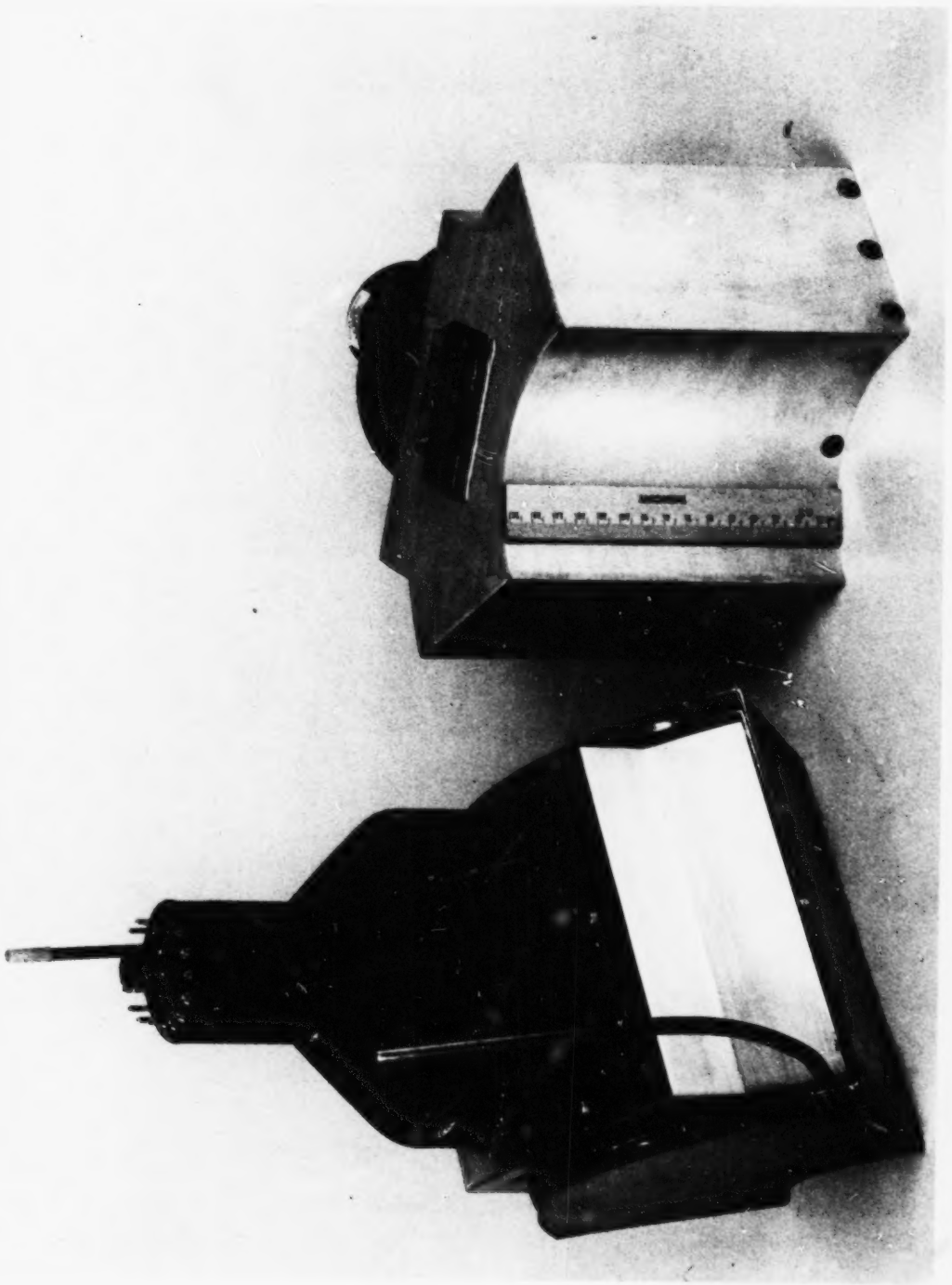
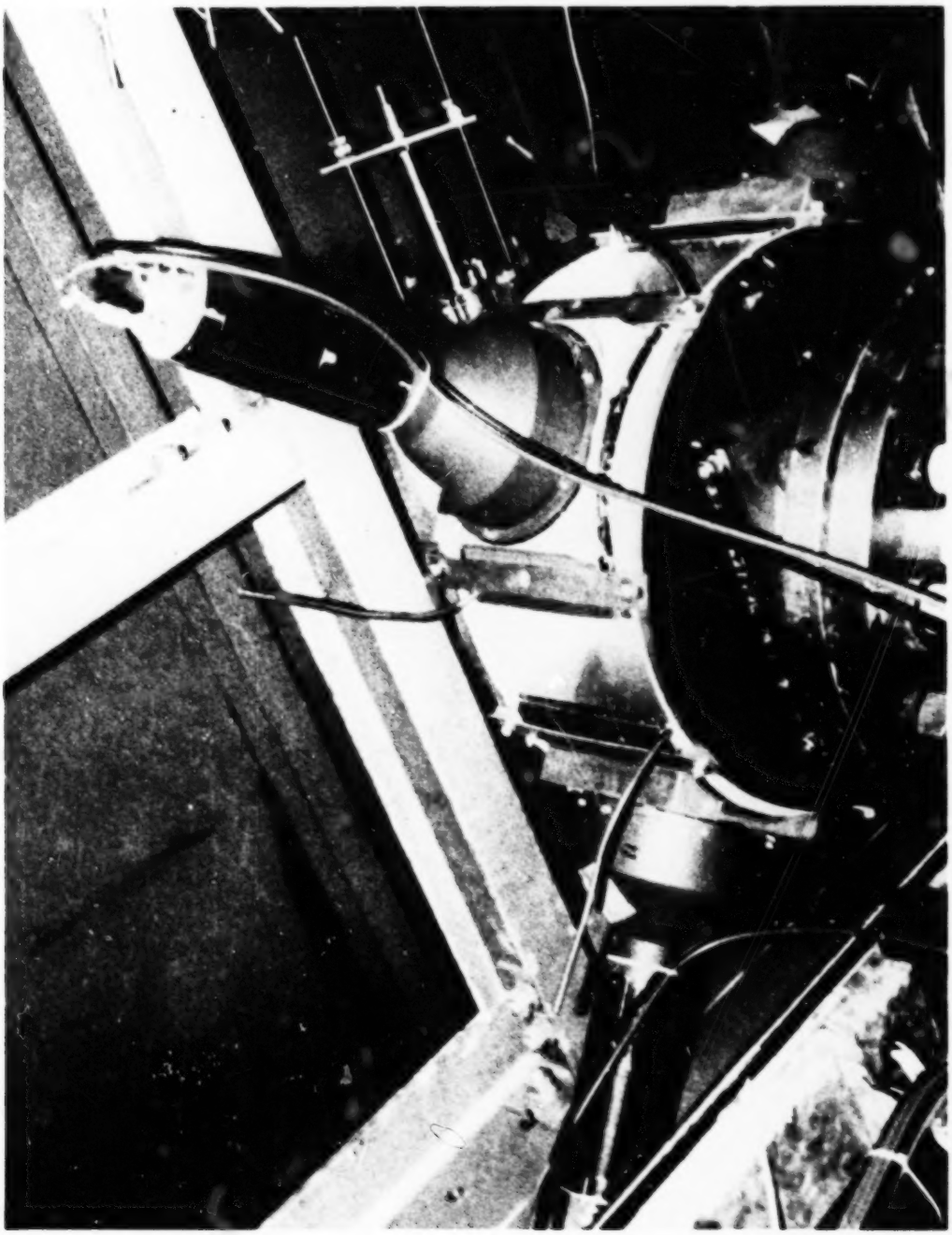


Fig. 5 PNA Detector at the PKL



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3.3 Data- Processing Equipment

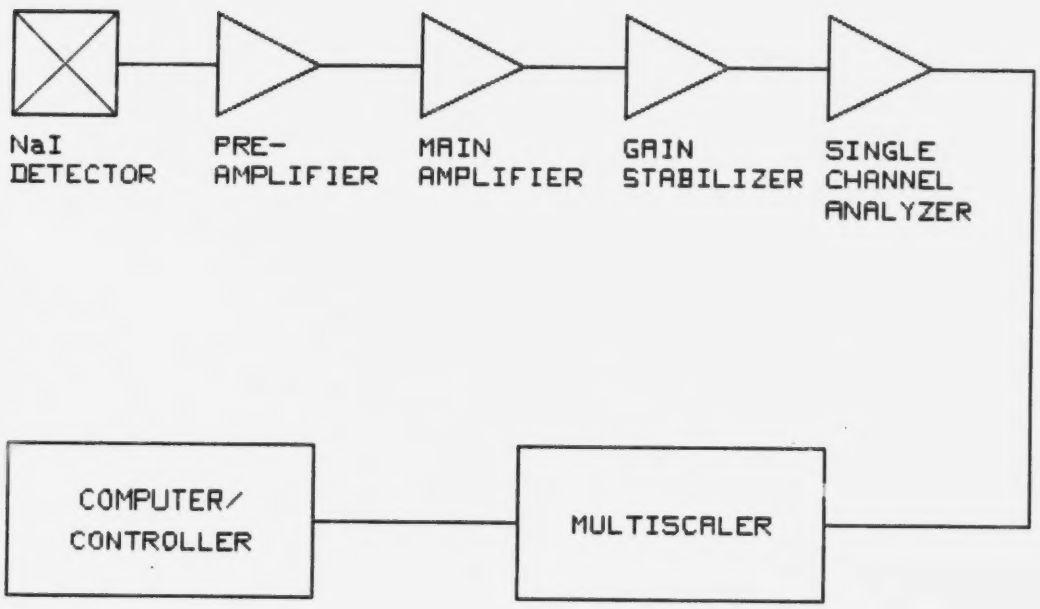
A block diagram of the equipment used for the processing of the detector signals is shown in Fig. 6. The NaI detector is described in the preceding Paragraph 3.2. The amplifiers and single-channel analyzers shown in Fig. 6 are common off-the-shelf items manufactured by several companies. The single-channel analyzers were operated in the discriminator mode, with the discriminator set at 1.5 MeV (above the 0.67-MeV Cs-137 peak).

Because of the exposure of the detector's scintillators and photomultipliers to the high temperatures normally found at reactor-simulating loops, gain stabilization of the whole detector system becomes necessary, even with cooling of the detector. With electronic stabilization, the detector needs to be cooled only to keep its temperature within the operating range, but not to keep it stable. We have tried two types of stabilizers, using separate stabilizers for each of the four segments of the detector. Both the Harshaw Model Na-23 and the Canberra Model 2050 stabilizers have performed satisfactorily in past tests. We used the Canberra stabilizer at the PKL.

Although the two stabilizers work by different principles, they both "lock" unto the peak of a reference source. We used small, 1- Ci Cs-137 sources as references for gain stabilization. These small reference sources were simply taped to an external surface of the detector segments.

In past PNA tests, we have used different makes of multichannel analyzers, operated in their multiscaler modes. For the present PKL test, we had to use a Packard Model 9012 MCA because, at that time, it was the only analyzer that could be interfaced on short notice with our computer. This MCA is no longer being produced and is rather outdated when compared to the newer models available today from various manufacturers. The biggest disadvantage of the Packard MCA is its slow data-transmission rate, which is geared to a teletype terminal. This analyzer limited the repetition rate of PNA measurements at the PKL. In future tests, faster analyzers will be used that will fully use the fast repetition rate of the neutron source, as described above. In the reported PKL test, however, where slow-break phenomena were studied at steady-state or slowly varying transient conditions, the slow data-transmission rate of the Packard analyzer was not too much of a handicap. Whenever necessary, four successive runs were recorded in the four segments of

Fig. 6 Block Diagram of Detector Electronics



PK-22102.01

the analyzer's memory, and data transmission and evaluation were then done after the four shots.

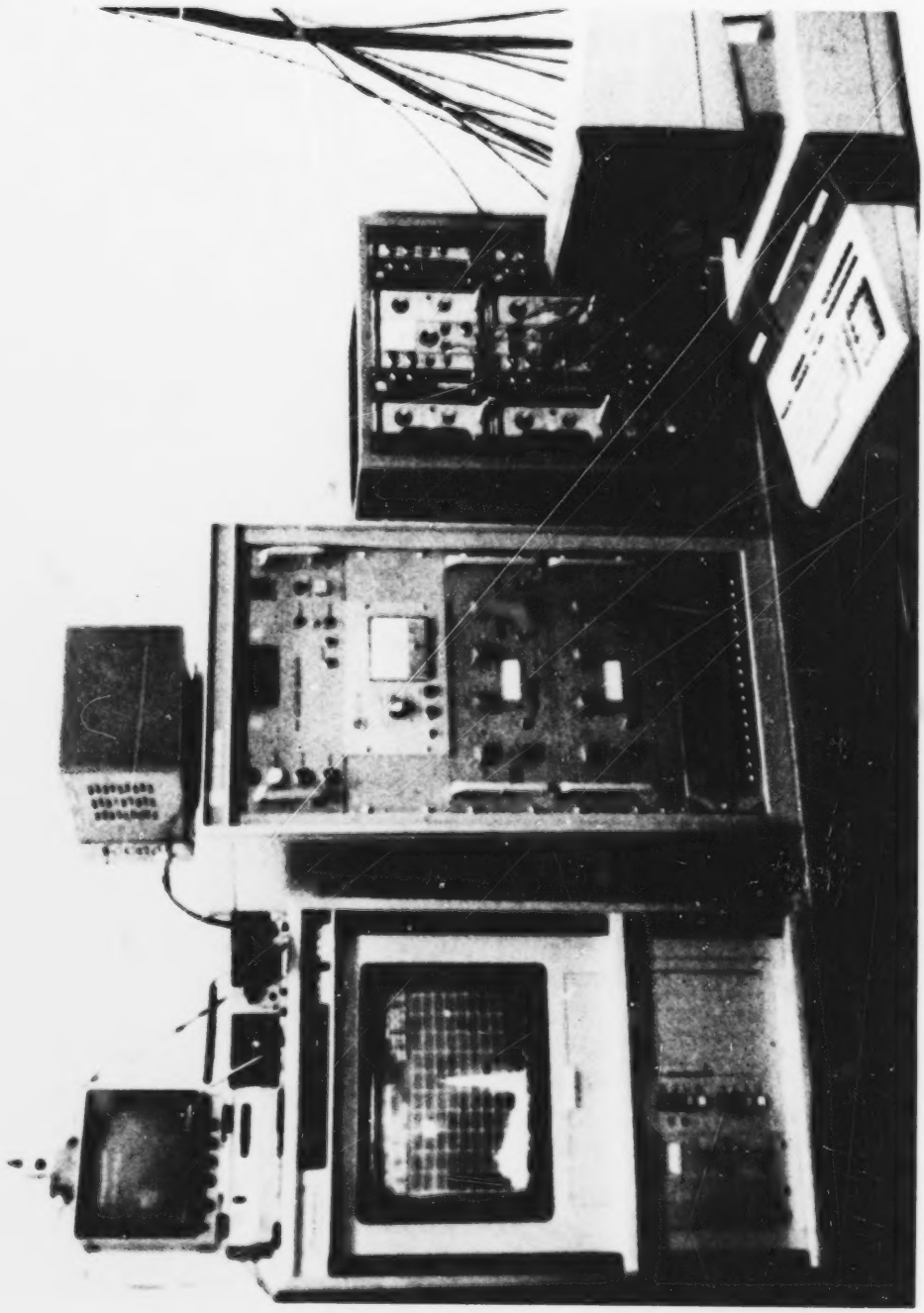
The PKL test was the first one in which PNA data were reduced completely automatically. This was done by an HP9845 computer. The operator of the computer could neither read nor alter the data- reduction program. The selection of the start and end channels of the integration range, as well as the background correction over this integration range, were fully automated. Velocity values derived by this azutomatic technique were then permanently stored on tape for retrieval of summary results.

Before each velocity measurement, the PNA operator had to select the length of the time channels in which the PNA counts were to be stored. Operating instructions specified that the time of arrival of the maximum of the distribution be estimated, and the channel length be chosen such as to place the maximum between channels 50 and 100. If this condition was not met, the automatically evaluated velocity values were presented in parentheses. (See Appendix B.)

Besides the automatic procedure, a manual data reduction was also possible. However, velocity data derived by subjective criteria were not stored permanently on tape.

Figure 7 is a photograph of the electronic data-processing equipment used at the PKL. The shown instruments are, left to right: The Packard Model 9012 analyzer, the control panel of the neutron source (also shown in Fig. 3), a rack holding the stabilizers, amplifiers and high- voltage power supplies for the four detector segments, and, finally, the HP 9845 computer.

Fig. 7 Photograph of Data-Processing Equipment.



4. FLOW MEASUREMENT BY PNA TECHNIQUES

The use of tracers for the study of various aspects of fluid flow goes back to the beginning of this century, when filaments of dye were used to visualize flow patterns in transparent pipes nad open channels. Allen and Taylor[3] were among the first researchers to inject salt into water mains and to determine the flow velocity of the water from the time of arrival of the salt at a detector located downstream of the injection point. Hull and Kent[4] used radioactive tracers to measure flow velocities in oil pipelines. With increasing availability of radioactive tracers and development of modern nuclear detectors, application of radioactive tracers for fluid-flow measurement became commonplace. Several good surveys of the various methods used today are vailable.[5-8] In most cases, reactor-produced radioactive isotopes are used, with half-lives of at least several hours (to allow transportation of the tracers from the reactor site to the site of the experiment). In such cases, the duration of the experiment is much shorter than the half-life of the radioisotope, and the decay of activity of the tracer during the experiment is negligible. In-situ production of short-lived radioactive tracers by the neutron-activation tchnique was first reported in 1971.[9]

Tracer techniques using reactor-produced isotopes (^{56}Mn and ^{40}Ar) were developed in Germany for the measurement of flow distributions and flow velocities of two-phase flow and were used successfully in water-reactor safety research.[10] Basically, these techniques could also be used for the measurement of flow velocities at the PKL. However, they are quite expensive and cumbersome, involving the handling of hundreds of Curies of radioactive material. Furthermore, since the half-lives of the radioisotopes used in this method are of the order of magnitude of hours, continuous experiments can be performed only until the holding tank is filled with radioactive water. Once the holding tanks are filled, the experiments must be discontinued in order to let the injected radioactivity to decay levels that can be discharged safely.

The use of neutron activation techniques has additional advantages over radioisotope tracer methods, such as nonintrusion into the pipe and uniform deposition of the tracer. Both continuous and pulsed neutron sources can be used for the activation of the fluid. The Argonne National Laboratory, having

had available portable pulsed neutron sources of high yields, has developed the pulsed-neutron activation technique to a very useful flow-measuring tool. For the measurement of (single- two-phase) flow of water, oxygen activation by the reaction $O^{16}(n,p)\ N^{16}$ is used, which results in a radioactive isotope, N^{16}, that decays with a half-life of 7.2 s under emission of a gamma ray of very high energy, E = 6.2 MeV. The short half-life of N^{16} is useful since the induced radioactivity about 1 mCi per pulse) decays fast and therefore does not require a holding tank for the activated fluid. The high energy of N^{16} was useful in penetrating the relatively thick steel wall of the downcomer of the PKL.

Proper interpretation of PNA-derived data can yield three independent measurements of flow velocities. The transit-time method and the decay-method yield values for the mass-flow velocity averaged over the source-detector spacing, and the total-count method yields cord-averaged velocity values at the detector location. The basic equations governing these methods, derived elsewhere,[11-13] are summarized below.

4.1 Transit-Time Method

For the measurement of mass-flow velocities in pipes, a pulsed neutron source is positioned close to the pipe, and the fluid opposite the source is activated by a short burst of neutrons (see Fig. 2). Ideally, the induced activity is originally confined to a narrow slice dZ and distributed uniformly over the cross sdection of the pipe. However, the original distribution of activity is changed as the activated fluid moves down the pipe, and a detector located downstream of the pipe will register a distribution of counts as the activated fluid moves past it. Conventionally, the average mass-flow velocity is then determined by deriving an average transit time for the activated slug of fluid, according to

$$U_M = Z_o \frac{1}{\bar{T}} . \qquad (1)$$

A large number of studies (including the classical work by Taylor[14,15]) deal with the dispersion of the injected tacers in time and with

numerical methods for the derivation of an "average transit time" suitable for use in Eq. 1. These methods derive an average transit time $\bar{T}$ from the time-distributed number of counts C(t), by using one of the following:
The mode t_o, where

$$dC(t_o)/dt = 0, \tag{2}$$

the median t', where

$$\int_0^{t'} C(t)dt = \int_{t'}^{\infty} C(t)dt, \tag{3}$$

or the mean $\bar{t}$, where

$$\bar{t} = \frac{\int_0 tC(t)dt}{\int_0 C(t)dt} . \tag{4}$$

Some authors have used only certain portions of the count-time distribution for the determination of $\bar{T}$. It was proposed, for example,[8] that the median value of the distribution between 20% (of the maximum) be used as a measure for $\bar{T}$. In our single-phase flow measurements,[16-19] we used the count-weighted mean of the reciprocal of the transit time, $\overline{(1/t)}'$, as a measure for $\overline{1/T}$ where

$$(\overline{\frac{1}{t}})' = \frac{\int_0 (\frac{1}{t})\, C(t)dt}{\int_0 C(t)dt} . \tag{5}$$

Use of this count-weighted mean of the reciprocal was first suggested by J. I. Sackett (Argonne National Laboratory, private communication, June 1971).

It should be pointed out that C(t) in Eqs. 2-5 is the decay-corrected number of counts per time channel, which is related to the background-corrected measured number of counts, c(t), as

$$C(c) = c(t)e^{t}, \qquad (6)$$

where

= decay constant of the radioactive isotope

and

t = time after irradiation of the fluid.

4.1.1 Basic Equation

Of the evaluation schemes shown in Eqs. 2-5, the one shown as Eq. 5 is believed to be the most accurate one, since it considers in the averaging process the inverse relation (Eq. 1) that exists between the velocity (the quantity of interest) and the transit time (the quantity measured in experiments). It should be pointed out that, in single-phase flow, all the evaluation schemes for $\bar{T}$ shown in Eqs. 2-5 converge to one value for long source-detector spacings. This is due to the fact that, for long source-detector spacings, the time distribution of counts becomes normal for laminar as well as for turbulent flow.[14,15] We have found, however, that none of these evaluation schemes were sufficiently accurate for application to two-phase flow conditions, where the distribution of counts is, in most cases, significantly different from normal distributions. In annular flows, for example, the liquid ring close to the pipe wall flows much slower than the mass at the centerline of the pipe. In many situations, there is a distinct separation of the velocities of the two phases, and the concept of "slip" can be used. Furthermore, the two-phase fluid does not fully mix over the short source-detector spacing normally used in PNA measurement.

For such complex two-phase flow conditions, a transit-time equation was derived directly from the definition for average mass flow as[11-13]

$$U_M = Z_o \frac{\frac{1}{t}\int_0^t A(t)dt}{\int_0^t A(t)dt} . \qquad (7)$$

where

U_M = average mass-flow velocity, and

$A(t)$ = the activity of the fluid passing the detector at the time t.

This is the basic transit-time equation of the PNA tchnique. Its further development depends on how the activation A(t) is measured. In some early radioisotope applications to gas-flow measurement, the activity was measured by ionization chambers installed directly on the pipe. In this case, the output signal was directly proportional to the activity of the gas. In most of the tracer studies performed with long-lived radioisotopes, samples were withdrawn from the fluiat regular intervals, placed into counting setups with reproducible geometry, and counted for a given length of time. In these cases, the number of counts was also proportional to the activity of the fluid. Because of the short half-lives commonly resulting from fast-neutron activation, PNA techniques are most useful in combination with fast transit times and short source-detector spacings. In such situations, activities are most conveniently measured by NaI detctors placed against the pipe wall, with counts being stored in the channels of a multichannel analyzer, operated in a multiscaler mode. With such a measurement setup, the number of counts registered by the detector during passage of an activity A(t) past the detector window Z is (see Fig. 2)

$$C(t) = C_2 A(t)\, t, \qquad (8)$$

where

C_2 = sensitivity of the detector (a constant)

and

t = residence time of the activity A(t) in the detector window Z,

with

$$t = \frac{Z}{U_D}, \tag{9}$$

where

U_D = the velocity of the activity A(t) past the detector window Z.

It was assumed above that the sensitivity of the detector, C_2 in Eq. 8, is constant for the entire cross section of the pipe. This condition can be approximated by mounting several detectors around the circumference of the pipe, or by using a ring-type detector completely encircling the pipe. With Eqs. 8 and 9, Eq. 7 becomes

$$U_M = Z_o \frac{\frac{1}{t}\int_0^t U_D C(t)dt}{\int_0^t U_D C(t)dt}. \tag{10}$$

Unfortunately, the velocity U_D is not directly measurable by PNA techniques. In situations describable as "streamlined" flow, i.e., for flows without significant mixing, the velocity past the detector window is obviously the same as the transit-time velocity between the source and the detector, or

$$U_D = U_T . \tag{11}$$

Such "streamlined" flow is found in two-phase flows with two separate flow velocities and in all practical (for PNA applicaiton) laminar flows. In streamlined flows, the instantaneous spatial flow-velocity distribution over the cross section of the pipe is identical to the velocity distribution measured by PNA techniques. In turbulent flows, the relation between U_D and U_T is not as easily seen, since the vigorous mixing of turbulent flows can distort the instantaneous velocity distributions to such a degree that they are not directly proportional to the velocity distribuitons measured by PNA techniques. Only a preliminary analysis of the flow velocities of the activated particles past the detector has been done.[20] However, a heuristic estimate of these velocities can be made as follows:

When a group of tagged particles with average transit velocities of U_T arrives at the detector window, their average instantaneous velocity will also be U_T, although some of the particles will have higher and some will have lower instantaneous velocities than U_T. While traversing the detector window, these particles will continue to mix with each other and with untagged particles and thus continue to change their axial velocities. If only mild mixing takes place during passage of these tagged particles through the detector window, then the average exit velocity of the particles leaving the detector window will also be U_T. Since both the entrance velocity and the exit velocity are equal to U_T in this case, the average velocity across the detector window, U_D, will also be equal to U_T, and Eq. 11 is valid for turbulent flow, too.

On the other hand, should all the particles entering the window with a velocity U_T mix completely during passage of these particles through the window, then their average velocity would become equal to the mass-averaged, PNA-derived flow velocity U_M (which is equal to the mean instantaneous flow velocity averaged over the cross section of the pipe). Now, our past experience has shown that mixing of turbulent flows is incomplete, even over common source-detector spacings Z_0. This conclusion was drawn from runs of the FORTRAN computer program OPTACT,[16,21] written for the modeling of the PNA technique, as well as from experiments in which two detectors were mounted on a pipe, one on the same side as the source and the other on the opposite side. Normally, the detector on the opposite side of the source shows a much lower counting rate than the detector mounted on the same side as the source. This implies incomplete mixing over the distance Z_0. Since $Z \ll Z_0$ in all situations, mixing is negligible during passage of the fluid through the detector window, and Eq. 11 is also valid for turbulent flow. This was verified analytically by use of the program PNASIM.[20] Thus, Eq. 11 is generally valid for all flow regimes.

The final form of the transit-time equation is now derived by combining Eqs. 10 and 11 and by setting $U_T = Z_0/T$, as

$$U_M = Z_0 \frac{\int_0^{t^2} \frac{1}{2} C(t)\,dt}{\int_0^{t} \frac{1}{t} C(t)\,dt}. \qquad (12)$$

Being derived from the definition of the mass-averaged flow velocity, Eq. 12 has no systematic error. The fundamental errors (due primarily to the finite collimation of the source and the detector) and the experimental errors (due to errors in measurement of times and distance, as well as to statistical errors), however, do affect the accuracy of the flow-velocity measurement by the transit-time method of the PNA technique. The magnitude of these two errors is discussed in Ref. 22.

4.1.2 Correction for Large Pipes

The basic PNA velociy equation (Eq. 12) is strictly valid only for pipes with diameters less than 10 cm. The diameter of the PKL downcomer is twice as large. As shown in Fig. 8, the radial activity distribution in pipes of this size can no longer be considered to be uniform; the specific activity at the centerline of the pipe is lower than the specific activity at the wall. Since the fluid at the wall is moving slower than the fluid at the center, the nonuniform radial activity distribution in large pipes tends to introduce a negative error into the PNA flow measurement; i.e., the measured mass-flow velocity is lower than the actual one.

A second requirement for universal validity of Eq. 12 is good collimation of the source and the detector; i.e., the source window dt and the detector window Z must be small in comparison to the source-detector spacing Z_o (see Fig. 2). This requirement was not met for the PNA test at the PKL, as shown in Fig. 9. Although the axial activity distribution shown in this figure is symmetric to the source position, a poorly collimated source (and similarly, a poorly collimated detector) will introduce a positive error into the PNA velocity measurment as can be seen from the following consideration:

The true flow velocity U_M, calculated from the transit time of a narrow "slug" of activity, is shown as Eq. 1,

$$U_M = Z_o \frac{1}{T} .$$

Fig. 8 Radial Activity Distribution

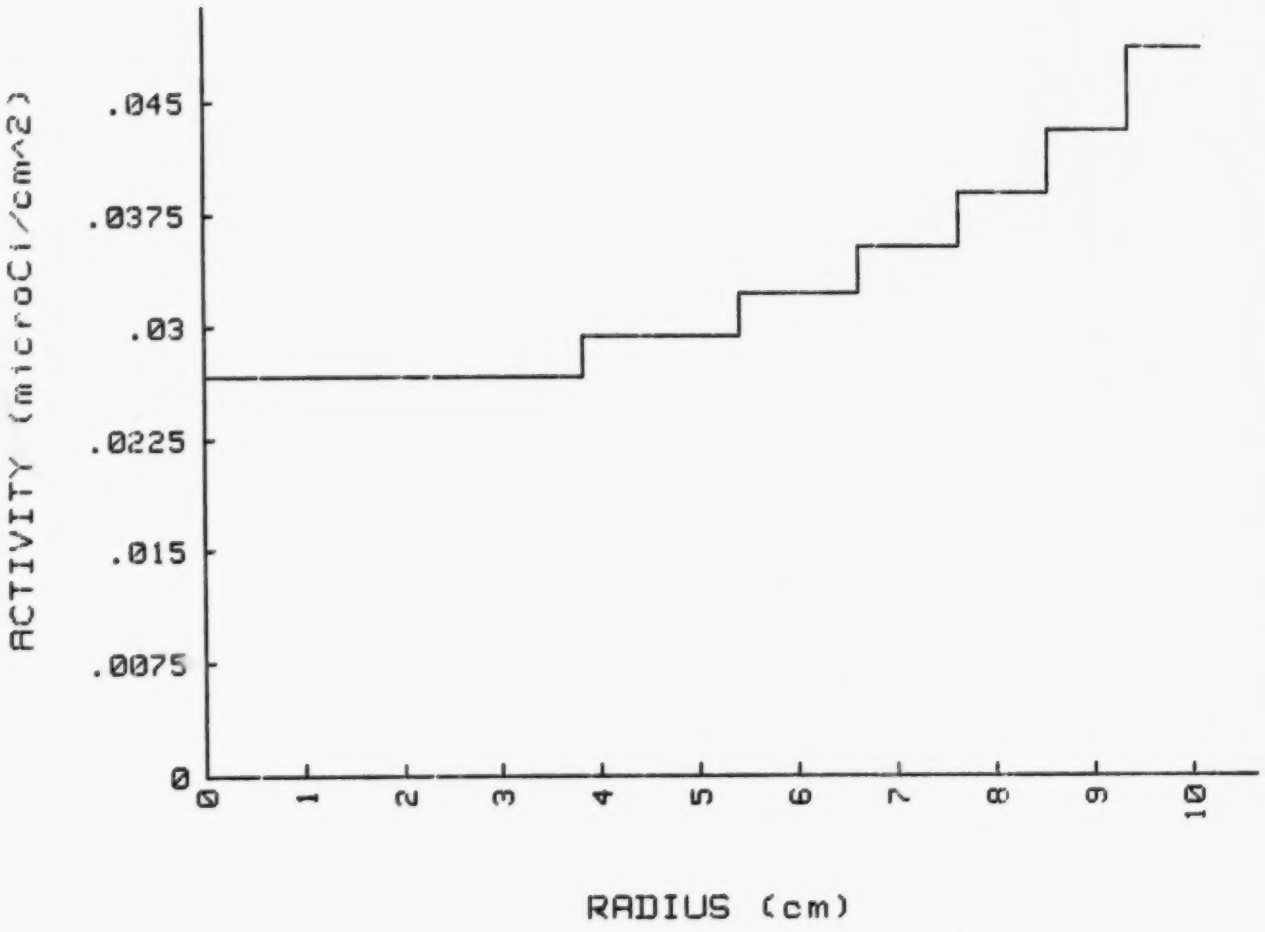
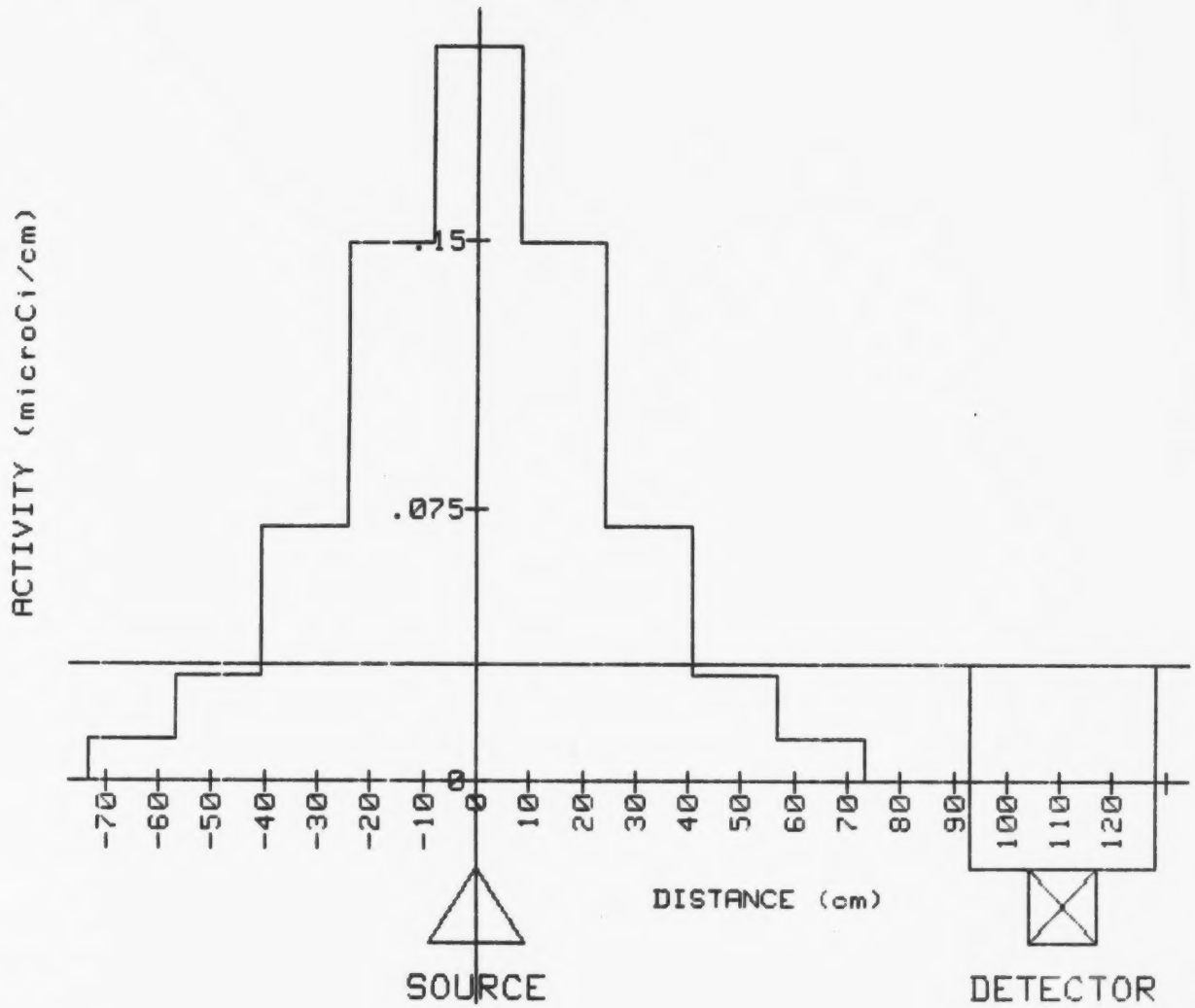


Fig. 9 Axial Activity Distribution



On the other hand, the velocity calculated from two narrow activity slugs, spaced symmetrically about T by ΔT, is

$$U_M' = \frac{Z_o}{2}\left(\frac{1}{T + \Delta t} + \frac{1}{T - \Delta t}\right) \tag{13}$$

$$= \frac{Z_o}{T - \Delta t^2},$$

or

$$U_M' > U_M . \tag{14}$$

The positive measurement error due to the extensive axial activity distribution is partially compensated by the negative measurement error due to the nonuniform radial activity distribution discussed above. Some thought was spent on how the effects of the nonuniform radial activity distribution and of the poor source collimation should be corrected by a properly chosen data-reduction technique. Correction factors to the basic PNA velocity equation (Eq. 12) could be applied in several different manners. For example, the distribution of the counts, C(t), could be corrected before entering it into Eq. 12. Or alternatively, an "effective" spacing Z_o could be derived by correcting the true spacing for effects of nonuniform and/or widely spaced activity distributions. A third method, the one preferred by me, consists of modifying the time exponent in the basic PNA velocity equation. In this approach, Eq. 12 is assumed to be a special case (with n = 2) of a general PNA velocity equation, which reads

$$U_M = Z_o \frac{\Sigma\, C(t)/t^n}{\Sigma\, C(t)/t^{n-1}} . \qquad (15)$$

The one feature of this method of correcting the basic PNA velocity equation that makes it very attractive is that a physical meaning can be asigned to various values of the exponent n. It was shown above that an exponent n = 2 must be chosen whenever the velocities of the activated mass elements at the detector are equal to their transit velocities (Eq. 11), and whenever a known relation exists between the transit time of a mass element and its transit velocity. Under adverse experimental conditions, one or both of these two requirements may not be met. For example, a disturbance of the flow between the source and the detector will modify or even destroy the correlation between transit velocity and detector velocity of the activated mass elements. A bend in the pipe and a DDT rake are examples for such flow disturbances. The most severe disturbance would be caused by a homogenizing screen installed right in front of the detector. Such a screen would completely destroy any relation between the transit velocity and the detector velocity of the activated mass elements. Nothing would be known about the

detector velocities of the individual mass elements, and one would have to assume a constant value for all of them (U_D = constant). For this condition, Eq. 10 yields

$$U_M = Z_o \frac{\Sigma\,(1/t)C(t)}{\Sigma\,C(t)}\,, \tag{16}$$

which is identical to Eq. 15 with a time exponent of n = 1.

For very extreme cases of poor source collimation, the fundamental relation on which the basic PNA velocity equation rests (i.e., Eq. 1) is not satisfied. For the situation depicted in Fig. 9, for example, the mass elements that are the first ones to arrive at the detector are not necessarily the fastest ones: some of these mass elements could have slow velocities, but could have been activated in close proximity of the detector. For very extreme situations, where there is no correlation between transit times and transit velocities, one must forego an attempt to interpret PNA test data in terms of mass-flow velocity, and must satisfy oneself with an "average transit time $\bar{t}$,"[11] derived by count-weighted averaging of the measured transit times:

$$\bar{t} = \frac{\Sigma\,t(i)C(i)}{\Sigma\,C(i)}\,. \tag{17}$$

This $\bar{t}$ is then used for the calculation of an "average velocity" $\bar{U}$ by

$$\bar{U} = Z_o/\bar{t}\,, \tag{18}$$

or

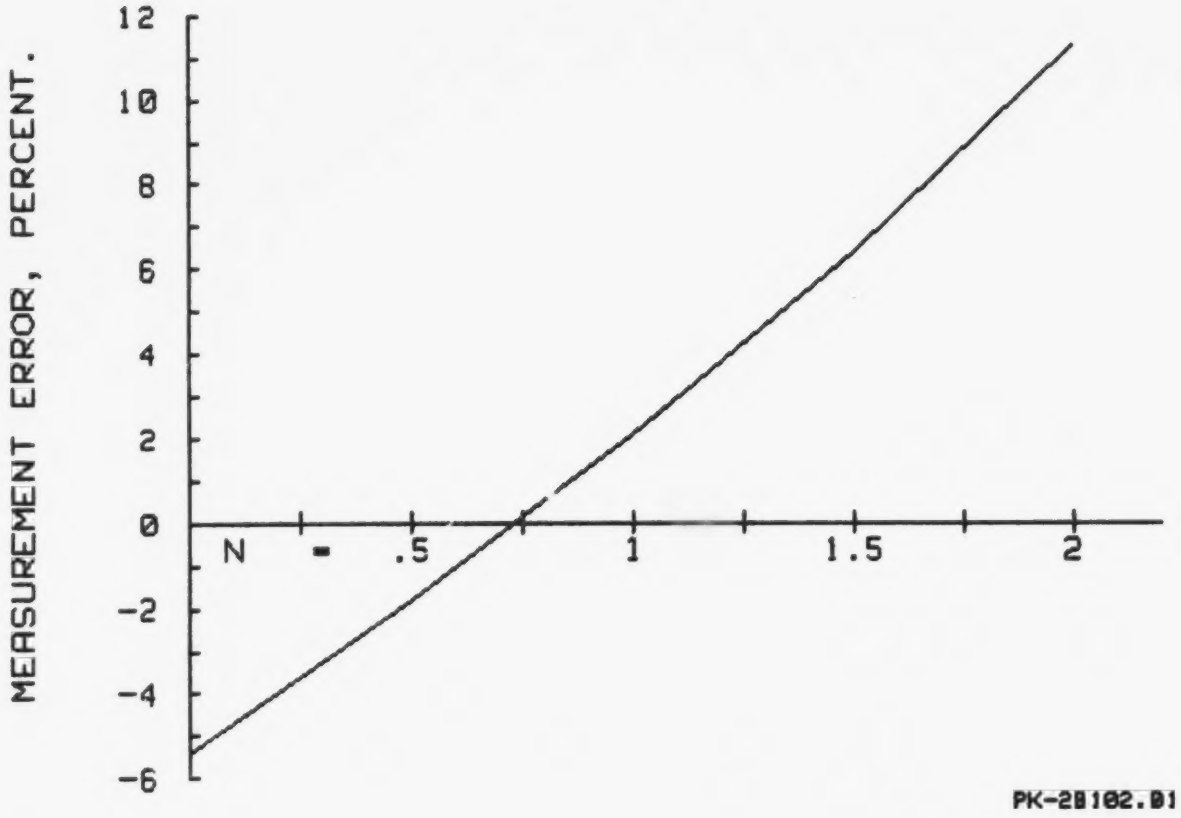
$$\bar{U} = Z_o \frac{\Sigma\,C(i)}{\Sigma\,C(i)t(i)}\,. \tag{19}$$

Equation 19 is identical to Eq. 16 with a time exponent of n = 0. Thus, physically meaningful interpretations can be given to the time exponents n = 2, n = 1, and n = 0 in the general PNA velocity equations. For large Z/R ratios, all these equations with values of n converge toward the same mass-flow velocity U_M. For smaller Z/R ratios, U_M does increase with increasing n. This latter fact can be used to adjust the PNA data-reduction technique to existing nonideal experimental conditions, and to choose a data-reduction technique that will result in a negligible measurement error. This task of optimizing the data-reduction technique can even be more generalized by allowing noninteger values for n, as well as $n > 2$.

PSASIM, a computer program simulating the PNA velocity-measurement technique, was used to derive an optimized time exponent n for the PKL test. PNASIM is an advanced version of ACT-OPT[16,21] and calculates the number of counts registered by the detector as a function of the transit time. PNASIM calculates the activity of the fluid activated by the pulsed neutron source, the transportation of this activity down the pipe (with a given velocity distribuiton and a given mixing of the fluid), and the detection of this activity by the detector. A mass-flow velocity U_M is then computed for different time exponents n, from the calculated counts distribution. That time exponent n for which the difference between the calculated mass-flow velocity U_M and the mass-flow velocity given as input to the program is zero, is then specified to be used for the reduction of the actual test data.

Figure 10 is a plot of the fundamental error of the PNA velocity reading for various time exponents n. The optimum time exponent n, i.e., that exponent for which the expected error of the velocity reading is zero, is n = 0.75.

Fig. 10 Fundamental PNA Velocity-Error



4.2 Decay Method

In Paragraph 4.1 above it is shown how a direct measurement of the transit time between the source and a detector can be used for the determination of the flow velocity. The transit time between two detectors can also be used for velocity determination.

With two detectors, the transit time can be measured in two different and independent ways. First of all, the time of passage of the activated "slug" past each of the two detectors can be measured, and the transit time can then be determined as the difference of these two times. This method is not a true mass-flow measuring technique but, instead, is affected by variations in the flow regime. It is useful, however, whenever the measured count distributions are nearly normally distributed and do not vary too much from test to test. This particular method was used for the measurement of the flow in the legs of the LOFT reactor,[23] since it was the only practical method in that application. The second method of measuring the transit time between two detectors in through the decay of the activity during the time of passage from the first to the second detector. If the activity passing the first detector is A_1, then the activity A_2 at the second detector will be

$$A_2 = A_1 e^{-\lambda T} , \tag{20}$$

where T = transit time between the two detectors.

The two detectors will register number of counts N_1 and N_2

$$\begin{aligned} N_1 &= C_1 A_1 \\ \text{and} \quad & \qquad , \\ N_2 &= C_2 A_2 , \end{aligned} \tag{21}$$

where C_1 and C_2 are the sensitivities of the detectors 1 and 2. The ratio of these two numbers is

$$N_1/N_2 = C_1 A_1 / C_2 A_2 = (C_1/C_2) e^{\lambda T} . \tag{22}$$

When the sensitivities of the two detectors are equal, $C_1 = C_2$,

$$N_1/N_2 = e^{\lambda T} \tag{23}$$

and $$T = \ln(N_1/N_2)/\lambda \ . \tag{24}$$

When the distance Z_D between the two detectors is known, then the flow velocity U can be determined by

$$U = Z_D/T \ . \tag{25}$$

This velocity U is not the true mass-flow velocity but, instead, is affected by changes in the flow regime.

4.3 Total-Count Method

The total-count method is yet another one to measure flow by the Pulsed-Neutron Activation technique. This method measures the average velocity of the fluid past the detector window ΔZ (See Fig. 2).

When A_o is the total activity produced in the fluid by one neutron pulse, then N_o, the total number of counts registered by the detector will be

$$N_o = C_1 A_o \ \Delta t. \tag{26}$$

Combination of this equation with Eq. 9 yields

$$N_o = (C_1 \Delta Z) \frac{A_o}{U_D} \ , \tag{27}$$

i.e., the total number of counts is proportional to the injected activity A_o and inversely proportional to the velocity U_D past the detector window.

The injected activity A_o is proportional to the source strength S which is measured by a neutron monitor (see Fig. 2 and Paragraph 3.1). The constant $C_1 \ \Delta Z$, although fixed throughout an experiment, is not known. Equation 27, therefore, is useful only for the relative measurement of flow velocities. One calibration point is necessary for absolute determination of

flow velocities by Eq. 27. However, since the measurement of the total number of counts is completely independent of the measurement of the transit time, comparison of the total-count data to the transit-time velocities furnishes a valuable tool for the detection of errors that might have occurred in the evaluation of certain test runs by the regular PNA relation given as Eq. 12 above. This self-check capability is another attractive feature of the PNA flow-measuring technique.

5. TEST DATA

Appendix B contains the test data (and coresponding plots) taken during PKL Run ID1. Data taken during the complete PKL-I test series are listed elsewhere.[24] All test data were evaluated by the computer program PNAPKL which is (partially) listed in Appendix A. This computer program first defines the boundary channels of the measured counts distribution. The total numbers of gross counts, integrated between the two boundary, channels are listed in column 2 of Table 2. In a second step, PNAPKL computes the background from the number of counts at the two boundary channels and in the last channel. The background b is expressed as a sum of a constant background b_o and a background b_a decaying with a half-life of $\lambda(b)$:

$$b = b_o + b_a e^{-\lambda(b)t}, \qquad (28)$$

where b_o, b_a, and λ are computed from the counts distribution by PNAPKL, and b is then subtracted from the measured counts in each of the time channels. The total numbers of backgound-corrected counts, summed between the boundaries of the counts distribution, are listed in column 3 of Table 2.

After background correction, the test data are corrected for decay according to Eq. 6. Net test data, corrected for background and decay, are used for the calculation of the mass-flow velocity according to Eq. 15, using a time-exponent of $n = 0.5$.

The total numbers of net counts, summed between the boundary channels of the measured distribution, are listed in column 4 of Table 2.

Table 2

Total Numbers of Counts

Run Number	Not Corrected	Background Corrected	Background and Decay Corrected
I.D.1.01	34,132	28,560	83,735
I.D.1.02	34,574	29,411	87,829
I.D.1.03	33,416	28,174	69,088
I.D.1.04	34,358	28,800	71,073
I.D.1.05	31,948	26,627	59,740
I.D.1.06	32,982	28,422	64,032
I.D.1.07	32,395	26,869	59,899
I.D.1.08	32,007	27,348	60,074
I.D.1.09	32,548	27,183	59,093
I.D.1.10	30,263	25,618	49,379
I.D.1.11	30,435	25,460	49,450
I.D.1.12	28,224	23,107	40,684
I.D.1.13	28,037	23,299	40,195
I.D.1.14	28,689	23,960	41,921
I.D.1.15	28,861	23,837	41,729
I.D.1.16	29,208	24,230	46,232
I.D.1.17	29,837	24,836	47,005
I.D.1.18	28,937	23,998	44,113
I.D.1.19	31,149	25,650	47,659
I.D.1.20	19,236	16,309	22,342
I.D.1.21	19,854	16,854	23,397
I.D.1.22	23,106	19,377	28,465
I.D.1.23	23,645	19,477	28,925
I.D.1.24	28,659	23,440	46,654
I.D.1.25	31,528	26,111	51,104
I.D.1.26	34,389	27,819	67,929
I.D.1.27	29,766	17,550	82,868
I.D.1.28	31,486	22,625	145,453

5.1 Accuracy of PNA Measurements

Although various methods can be used for velocity measurements by PNA techniques (see Section 4), we used the one utilizing transit times derived from the measured counts-vs-time distributions, as described in Paragraph 4.1. Calculations performed with the computer progrma PNASIM have shown (Fig. 10) that a negligible systematic error can be expected if a time-exponent n = 0.75 is used in the general PNA equation, Eq. 15. This value for n was derived in a thorough analysis performed after the test at the PKL. We are rather confident in the validity of Fig. 10 because of the excellent agreement between the measured count distributions and those predicted by the program PNASIM, a shown in Fig. 11. Unfortunately, a time exponent of n = 0.5 had been specified for the reduction of test data, before the analytical study that was performed after the test. The PNA velocity values published in this report and in Ref. 24 were computed with a time exponent of n = 0.5 (see listing of program PNLDAT, Appendix A) and are, therefore, probably too low by about 2%.

Besides of this fundamental error of 2% in the PNA velocity reading, the PNA data are also affected by the uncertainties in the time and distance measurements and by uncertainties due to the statistical nature of the accumulated counts.[22] These two latter errors were estimated to be less than 0.5% and 1%, respectively, so that the total error (standard deviation) of the PNA velocity readings can be expected to be less than 3%.

For some of the test conditions at the PKL, flow velocities in the downcomer could be measured by venturi meters or could be calculated by thermal-balance calculations from the inlet and outlet temperatures of the electrically heated core. The measurements by these two conventional techniques compared well with PNA-derived data, as shown in Fig. 12 and Table 3 (from Reference 24).

Fig. 11 Comparison of Predicted to Measured Distribution

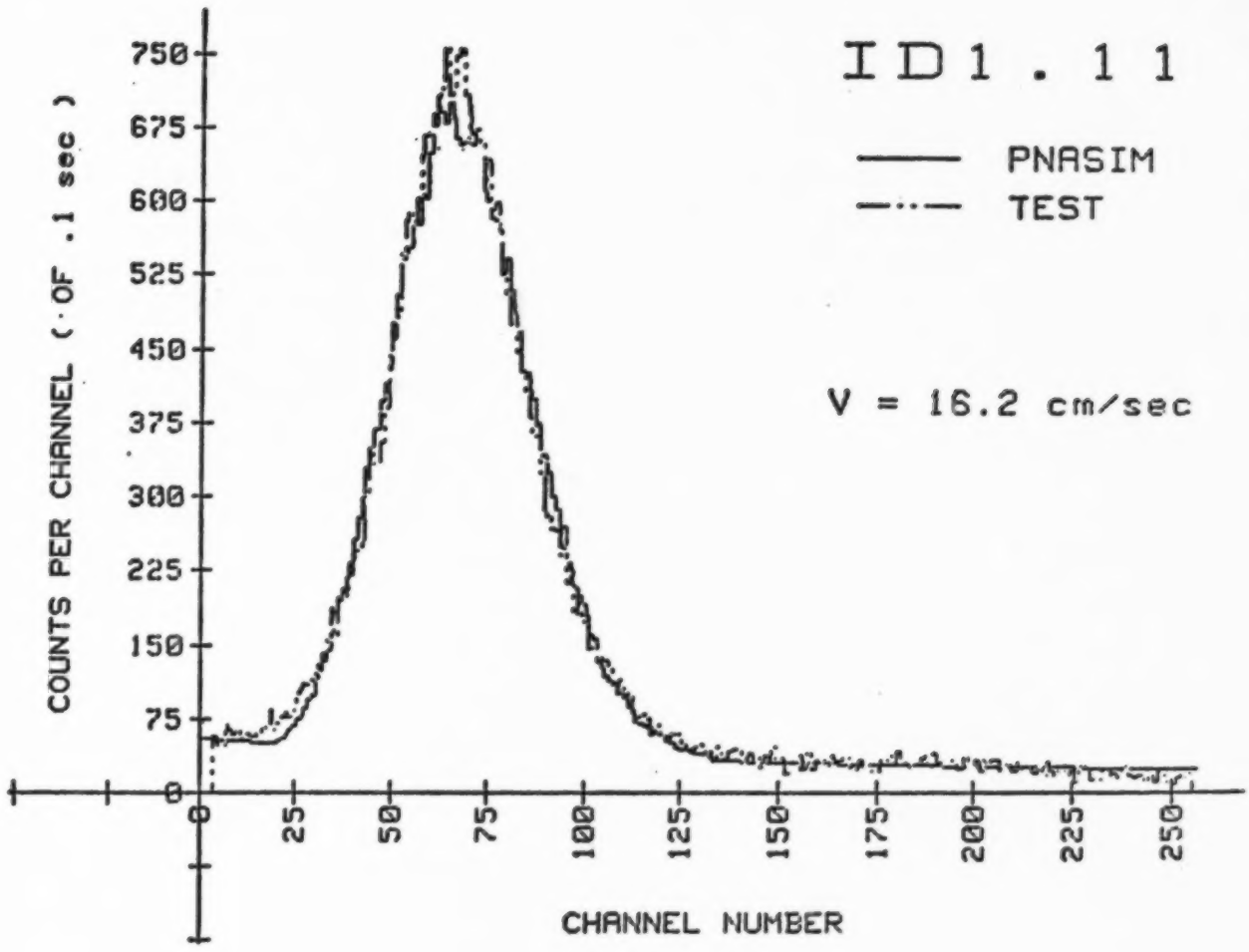
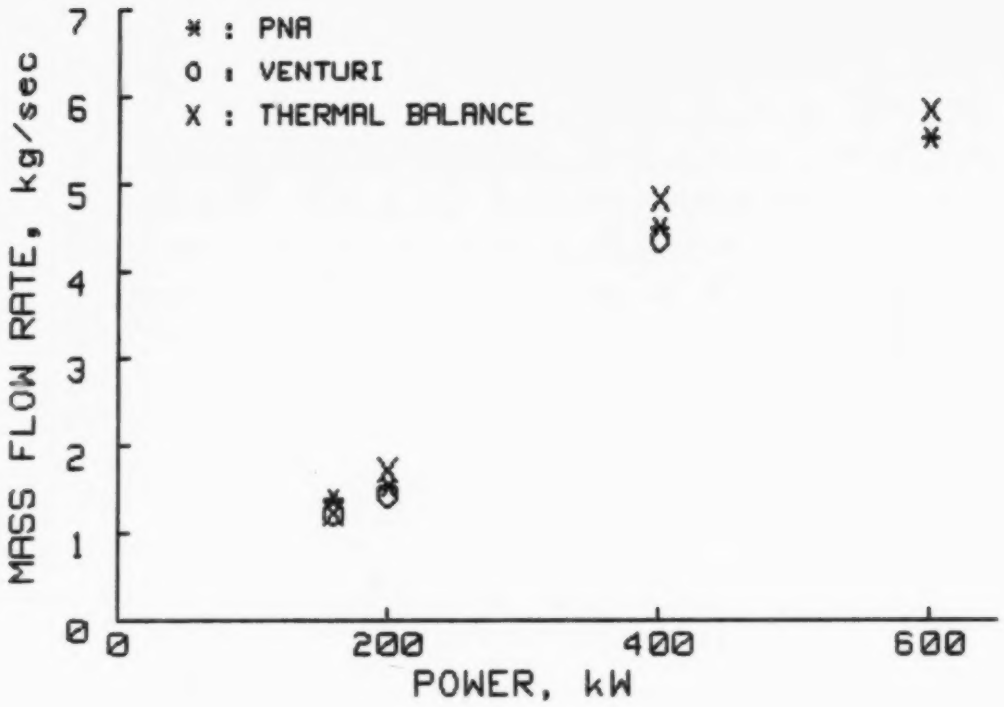


Fig. 12 Comparison of PNA Data With Other Readings



PK-28101.02

Table 3

Comparison of PNA Data With Other Readings

Power (kW)	Mass-Flow Rate (kg/s)		
	PNA	Venturi	Thermal Balance
160	1.39	1.22	1.23
200	1.52	1.44	1.71
400	4.50	4.36	4.83
600	5.52	--	5.84

5.2 PNA Velocity Readings

Test data (Appendix B) were evaluated by the computer program PNADAT (Appendix A) and Eq. 15, using a time-exponent of n = 0.5. The program was secured and could not be listed or altered during the test. Automtically calculated flow velocities were stored permanently on data cassettes of the HP 9845 computer. Integration ranges could also be selected manually, but the flow velocities calculated with manually selected ranges could not be stored permanently on data cassettes. Table 4 lists the test results of the test ID1, stored on cassette #1. A complete set of PNA velocities is published in Reference 24.

Instructions for the operation of the PNA equipment specified selection of Δt, the length of the time channels of the multiscaler, so that the peak of the counts distribution would fall between the channels 50 and 100. The operator did not always succeed in estimating the flow velocity well enough to meet this specification. In some cases (Run ID1.27, Appendix B, for example), the peak fell outside the specified channel range. In such cases, the accuracy estimates of PNA-derived velocity readings (Paragraph 5.1) are no longer valid, and velocities calculated from thse runs are displayed in parentheses in Table 4.

For comparison purposes, the velocities for test ID1 were also calculated by the total-count method and the decay method. Results obtained by these two methods, and the deviations of the velocities derived by these two methods from the velocity derived by the regular transit-time method, are listed in Table 5 and plotted in Fig. 13.

Table 4

Flow Velocities, Test ID1

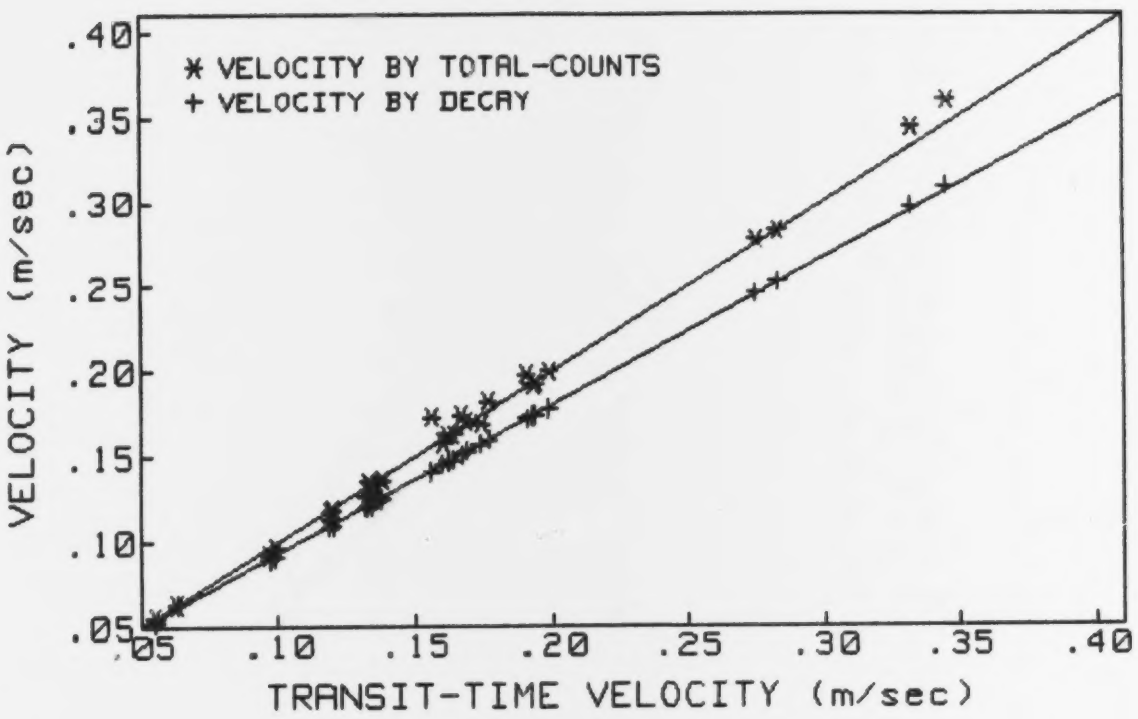
FILE NUMBER	RUN NUMBER	REMARKS
1	SPECTR	Data Not Reduced
2	BACKGR	Data Not Reduced
3	ID1.01	Flow Velocity =(.099)m/sec
4	ID1.02	Flow Velocity = .097 m/sec
5	ID1.03	Flow Velocity = .119 m/sec
6	ID1.04	Flow Velocity = .119 m/sec
7	ID1.05	Flow Velocity = .133 m/sec
8	ID1.06	Flow Velocity = .132 m/sec
9	ID1.07	Flow Velocity = .134 m/sec
10	ID1.08	Flow Velocity = .136 m/sec
11	ID1.09	Flow Velocity = .138 m/sec
12	ID1.10	Flow Velocity = .164 m/sec
13	ID1.11	Flow Velocity = .162 m/sec
14	ID1.12	Flow Velocity = .191 m/sec
15	ID1.13	Flow Velocity = .199 m/sec
16	ID1.14	Flow Velocity =(.193)m/sec
17	ID1.15	Flow Velocity =(.194)m/sec
18	ID1.16	Flow Velocity =(.167)m/sec
19	ID1.17	Flow Velocity =(.169)m/sec
20	ID1.18	Flow Velocity = .177 m/sec
21	ID1.19	Flow Velocity = .174 m/sec
22	ID1.20	Flow Velocity =(.345)m/sec
23	ID1.21	Flow Velocity =(.332)m/sec
24	ID1.22	Flow Velocity = .283 m/sec
25	ID1.23	Flow Velocity = .275 m/sec
26	ID1.24	Flow Velocity = .156 m/sec
27	ID1.25	Flow Velocity = .160 m/sec
28	ID1.26	Flow Velocity = .120 m/sec
29	ID1.27	Flow Velocity =(.067)m/sec
30	ID1.28	Flow Velocity = .055 m/sec
31	ID1.29	Flow Velocity = .000 m/sec

Table 5

Comparison of PNA Methods

Run Number	Transit Time (m/s)	Total Count Velocity (m/s)	Total Count Delta (%)	Decay Velocity (m/s)	Decay Delta (%)
I.D.1.01	0.099	0.096	-3.0	0.090	-9.1
I.D.1.02	0.097	0.092	-5.2	0.089	-8.2
I.D.1.03	0.119	0.117	-1.7	0.108	-9.2
I.D.1.04	0.119	0.113	-5.0	0.108	-9.2
I.D.1.05	0.133	0.135	1.5	0.120	-9.8
I.D.1.06	0.132	0.126	-4.5	0.120	-9.1
I.D.1.07	0.134	0.134	0.0	0.121	-9.7
I.D.1.08	0.136	0.134	-1.5	0.124	-8.8
I.D.1.09	0.138	0.136	-1.4	0.125	-9.4
I.D.1.10	0.164	0.163	-0.6	0.148	-9.8
I.D.1.11	0.162	0.163	0.6	0.147	-9.3
I.D.1.12	0.191	0.198	3.7	0.172	-9.9
I.D.1.13	0.199	0.200	0.5	0.178	-10.6
I.D.1.14	0.193	0.192	-0.5	0.174	-9.8
I.D.1.15	0.194	0.193	-0.5	0.174	-10.3
I.D.1.16	0.167	0.174	4.2	0.15	-9.6
I.D.1.17	0.169	0.171	1.2	0.153	-9.5
I.D.1.18	0.177	0.182	2.8	0.160	-9.6
I.D.1.19	0.174	0.169	-2.9	0.157	-9.8
I.D.1.20	0.345	0.360	4.3	0.309	-10.4
I.D.1.21	0.332	0.344	3.6	0.197	-10.5
I.D.1.22	0.283	0.283	0.0	0.253	-10.6
I.D.1.23	0.275	0.278	1.1	0.246	-10.5
I.D.1.24	0.156	0.173	10.9	0.141	-9.6
I.D.1.25	0.160	0.158	-1.3	0.145	-9.4
I.D.1.26	0.120	0.119	-0.8	0.109	-9.2
I.D.1.27	0.067	0.096	(43.3)	0.063	-6.0
I.D.1.28	0.055	0.055	0.0	0.052	-5.5
Average			0.2		-9.4

Fig. 13 Comparison of PNA Methods



PK-29103.01

Relative total-count velocities were calculated by Eq. 27, using the background-corrected data in column 3 of Table 2. The calculated velocity values were normalized for the average difference between the total-count velocities and the transit-time velocities to be about zero. The total-count velocity of Run ID1.27 is much too high because the contribution of slow-flowing regions was neglected due to the cutoff of the counts distribution at long transit times (see Appendix B). The smaller differences of the other runs are believed to be due primarily to fluctuations in the reading of the neutron monitor.

The transit time T was calucalted by the decay method according to Eq. 23. A fictitious detector of the same sensitivity as the real detector was assumed to be located at the source position, and the "counts" of this detector were assumed to be equal to those listed as "background- and decay-corrected" in column 4 of Table 2. Since the decay correction of the data listed in Table 2 was performed using measured transit times, the velocity values derived by the decay method (column 5 in Table 5) are, in this particular case, absolute but not independent of the transit-time velocities listed in column 2 of Table 5. The decay-velocity data reveal, however, one interesting feature of the decay method.

The fact that all velocities derived by the decay method are about 9% lower than the velocities derived by the transit-time method, could be interpreted in meaning that the decay method is sensitive to radial distribuitons of activity as shown in Fig. 8, but insensitive to axial distributions as shown in Fig. 9. Its sensitivity to radial activity distribution is obvious. Since the slower outer regions in a pipe are more intensely activated and also are preferentially detected, they contribute more than their share to the average velocity measurement. The insensitivity of the decay method to axial activity distributions is not so obvious, but can be understood by a simple analytical example as follows.

Let A_o be the activity of an activated slug at the first detector, A its activity at a second detector, and its transit time T between the detectors determined by Eq. 20:

$$A = A_o e^{-\lambda T} . \tag{29}$$

Now, let's assume that the activated slug be divided into two slugs of equal activity, $A_o/2$, and that the transit time of the first slug be $T + \Delta T$ and the transit time of the second slug be $T - \Delta T$. Then, the activities of these two slugs at the second detector will be

$$A_1 = \frac{A_o}{2} e^{-\lambda(T+\Delta T)}$$

and (30)

$$A_2 = \frac{A_o}{2} e^{-\lambda(T-\Delta T)},$$

and the sum of these two activities will be

$$A_1 + A_2 = \frac{A_o}{2} e^{\lambda T} (e^{-\lambda \Delta T} + e^{\lambda \Delta T}) . \tag{31}$$

For small ΔT, $\lambda \Delta T \approx 0$, and using the first terms of a Taylor series for the exponential terms in the brackets:

$$A_1 + A_2 = \frac{A_o}{2} e^{-\lambda T}(1 - \lambda \Delta T + 1 + \lambda \Delta T), \tag{32}$$

and, with Eq. 29;

$$A_1 + A_2 = A_o e^{-\lambda T} = A. \tag{33}$$

Thus, a total activity A_o at the first detctor will appear as an activity A at the second detector, even if it goes down the pipe in separated smaller slugs of activated fluid (axially dispersed) instead of in one concentrated slug (not axially dispersed).

5.3 Test Results

The PNA velocity readings performed on the downcomer of the PKL were the primary system used for the measurement of the total flow through the facility during the small-break LOCA simulation runs. Many test parameters were varied during this small-break test series to investigate system response to various, steady-state and slowly transient conditions. Data taken at these tests were reduced and published by PKL staff.[25,26] The most important conclusion to be drawn from this test series is, probably, recognition that decay heat can be removed from the core by the steam generators' secondary flow as long as fluid (single-or-double-phase) is covering the core. Effective heat transfer takes place in small LOCA's in single and two-phase natural circulation as well as in the reflux condenser mode.

6. MEASUREMENTS PROPOSED FOR PKL-II

After completion of the small-break test series, modification of the PKL-I facility was begun (to PKL-II) for studies of reflood and end-of-blowdown phenomena occurring at large-break LOCA's. Two-phase fluid of low density will flow through the system at high velocities in the proposed test series. PNA measurements of mass-flow velocities and global densities could be performed at two locations on the PKL-II, using data- reduction techniques applicable to large-diameter pipes.[13] The two locations at which PNA tests could be usefully performed are the downcomer, at the same location as used in the PKL-I tests (Position 1), and the broken loop leading to the steam generator inlet (Position 2). The quality, void fraction, mass-flow velocity, and global density to be expected at these two locations are listed in Table 6. PNASIM computer runs were performed to predict the number of expected counts for these conditions. Using one neutron source (as in the PKL-I tests, but mounted closer to the pipe) and two PKL-I detectors (available at ANL), the predicted total number of counts, N, and the expected error σ (standard deviation) of mass flow readings ($\dot{m}$) are also listed in Table 6.

Table 6

Flow Conditions at PKL-II

Position	Pipe Diameter (cm)	x	α	V (m/s)	ρ (g/cm^3)	N (counts)	σ 1%
I	20.3	0.6	0.99	21.0	0.021	600	6
		0.17	0.94	4.8	0.063	7,000	2
		0.53	0.99	8.9	0.021	1,300	4
II	11.3	0.29	0.96	22.0	0.046	800	5
		0.52	0.99	40.0	0.021	200	10
		0.24	0.95	12.9	0.054	1,500	4

7. CONCLUSIONS

As opposed to conventional flow-measuring devices, PNA flow-measuring systems work best for slow flows and at high densities. This was shown during the slow-break simulation runs performed at the PKL-I facility. Capability to measure slow flows, therefore, can now be added to the list of two other experimentally demonstrated capabilities of the PNA flow-measuring techniques, i.e., the on-line calibration of two-phase flow instruments and the measurement of flow distributions in large systems.

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Appendix A

Listing of PKLDAT

```
10     ! THIS IS PROGRAM PKLDAT.
20     !
30     !
40     OPTION BASE 1
50     DEG
60     DIM Xy(4,256)
70     !
80     ! Xy(1,I)=ORIGINAL DATA       Xy(2,I)=SMOOTHED DATA      Xy(3,1)=NET DATA
90     !
100    PRINTER IS 16
110    PRINT PAGE
120    DISP " "
130    PRINT "YOU ARE USING PROGRAM PKLNRC"
140    BEEP
150    INPUT "ENTER NUMBER OF CASSETTE BEING USED",Cassette
160    !-------------------------------------------------------------------------
170    Avechannel=11                                                ! SPECIFICATIONS
180    Decayconstant=LOG(2)/7.2
190    Searchchannel=50
200    Timexponent=.5
210    !-------------------------------------------------------------------------
220    PRINT PAGE                                                   ! PROGRAM SELECTION
230    ON KEY 0 GOSUB Listcassette
240    ON KEY 1 GOSUB Listfile
250    ON KEY 2 GOSUB Reducefile
260    PRINTER IS 16
270    PRINT PAGE
280    DISP " "
290    PRINT "KEY 0 LISTS THE DATA STORED ON THE CASSETTE.",LIN(1)
300    PRINT "KEY 1 LISTS AND PLOTS THE CONTENTS OF A DATA FILE.",LIN(1)
310    PRINT "KEY 2 EVALUATES TEST DATA STORED IN A SPECIFIED FILE.",LIN(1)
320    Startup=0
330    BEEP
340    DISP " COMPUTER WAITING. PRESS ONE OF THE KEYS LISTED ABOVE."
350    IF Startup=1 THEN 260
360    GOTO 340
370    !-------------------------------------------------------------------------
380  Assignfile: ASSIGN @1 TO "F"&VAL$(Filenumber)&":T15"
390    RETURN
400    !-------------------------------------------------------------------------
410  Dumpfile: PRINTER IS 0
420    PRINT PAGE,LIN(5)
430    PRINT "RUN NUMBER = ";Runnumber$,LIN(1)
440     FOR I=1 TO 32
450     J=(I-1)*8
460     PRINT USING 470;J,Xy(1,J+1),Xy(1,J+2),Xy(1,J+3),Xy(1,J+4),Xy(1,J+5),Xy(1,
J+6),Xy(1,J+7),Xy(1,J+8)
470     IMAGE DDD,8X,8(DDDDDDD,X)
480     NEXT I
490    RETURN
500    !-------------------------------------------------------------------------
510  Dumpdata:    PRINT LIN(1),"SPACING = ";Spacing
520    PRINT "DELTA TIME = ";Deltatime
530    PRINT "START CHANNEL = ";Startchannel
540    PRINT "END CHANNEL = ";Endchannel
550    PRINT "START COUNTS = ";Startcounts
560    PRINT "END COUNTS = ";Endcounts
570    PRINT "CONSTANT BACKGROUND = ";B0
580    PRINT "DECAYING BACKGROUND = ";Ba
590    PRINT "DECAY CONSTANT OF BACKGROUND = ";Lambda
600    PRINT "NEUTRON MONITOR = ";Neutronmonitor
610    IF Flowvelocity>=0 THEN PRINT USING 630;"FLOW VELOCITY = ";Flowvelocity
620    IF Flowvelocity<0 THEN PRINT USING 630;"FLOW VELOCITY =(";ABS(Flowvelocity
);")"
630    IMAGE 21A,D.DDD,A
640    PRINT "TOTAL NUMBER OF COUNTS = ";PROUND(Totalcounts/Neutronmonitor,0)
```

```
650   PRINT "NUMBER OF BACKGROUND CORRECTED COUNTS = ";PROUND(Totalnet/Neutronmo
nitor,0) !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
660   PRINT "NUMBER OF BACKGR/DECAY CORRECTED COUNTS = ";PROUND(Totalcorr/Neutro
nmonitor,0) !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
670   RETURN
680   ! ------------------------------------------------------------------------
690 Readfile:  READ #1;Runnumber$,Flowvelocity
700    FOR I=1 TO 256
710    READ #1;Counts
720    Xy(1,I)=Counts
730    NEXT I
740   READ #1;Spacing,Deltatime,Startchannel,Endchannel,Startcounts
750   READ #1;Endcounts,B0,Ba,Lambda,Neutronmonitor
760   RESTORE
770   RETURN
780   ! ------------------------------------------------------------------------
790 Listcassette:   PRINTER IS 16
800   PRINT PAGE
810   DISP " "
820   PRINTER IS 0
830   PRINT PAGE,LIN(5)
840   DISP " "
850   PRINT "FILES STORED ON CASSETTE NUMBER ";Cassette;" ARE:",LIN(2)
860   PRINT "FILE NUMBER         RUN NUMBER          REMARKS",LIN(1)
870   Istart=(Cassette-1)*40
880    FOR I=Istart+1 TO Istart+40
890    Filenumber=I
900    GOSUB Assignfile
910    READ #1;R$,F
920    IF R$="0" THEN Remarks$="No Data Stored"
930    IF (R$<>"0") AND (F=0) THEN Remarks$="Data Not Reduced"
940    IF (R$<>"0") AND (F>0) THEN Remarks$="Flow Velocity = "
950    IF (R$<>"0") AND (F<0) THEN Remarks$="Flow Velocity =("
960    IMAGE 4X,3D,12X,6A,12X,10A,D.DDD,6A
970    IF F=0 THEN PRINT USING 960;Filenumber,R$,Remarks$
980    IF F>0 THEN PRINT USING 960;Filenumber,R$,Remarks$,F," m/sec"
990    IF F<0 THEN PRINT USING 960;Filenumber,R$,Remarks$,ABS(F),")m/sec"
1000   NEXT I
1010  Startup=1
1020  RETURN
1030  ! ------------------------------------------------------------------------
1040 Listfile:  PRINTER IS 16
1050  PRINT PAGE
1060  DISP " "
1070  INPUT "ENTER NUMBER OF FILE YOU WANT TO USE.",Filenumber
1080  GOSUB Assignfile
1090  GOSUB Readfile
1100  Record=1
1110  GOSUB Dumpfile
1120  GOSUB Dumpdata
1130  PRINTER IS 0
1140  PRINT PAGE,LIN(5)
1150  GOSUB Plots
1160  Startup=1
1170  RETURN
1180  ! ------------------------------------------------------------------------
1190 Reducefile:  PRINTER IS 16
1200  PRINT PAGE
1210  DISP " "
1220  BEEP
1230  INPUT "ENTER THE NUMBER OF THE FILE YOU WANT TO EVALUATE.",Filenumber
1240  GOSUB Assignfile                                                    ! PE
1250  GOSUB Readfile
1260  PRINTER IS 0
1270  PRINT PAGE,LIN(5)
1280  GOSUB Plots
```

```
1290  GOSUB Computerange
1300  BEEP
1310  DISP "THE FLOW VELOCITY IS NOW BEING COMPUTED."
1320  GOSUB Computeflow
1330  DISP " "
1340  PRINTER IS 0
1350  PRINT PAGE,LIN(3)
1360  PRINT "FILENUMBER: ";Filenumber;"          RUNNUMBER: ";Runnumber$
1370  PRINT "THESE ARE THE REDUCED DATA:",LIN(1)
1380  GOSUB Dumpdata
1390  Startup=1
1400  RETURN
1410  ! ------------------------------------------------------------------------
1420 Computerange: BEEP
1430  DISP "THE INTEGRATION LIMITS ARE NOW BEING COMPUTED."
1440   Aux=(Avechannel-1)/2
1450    FOR I=1 TO Aux+2
1460    Xy(2,I)=0
1470    NEXT I
1480    !
1490    FOR I=Aux+3 TO 255-Aux
1500    Xy(2,I)=0
1510     FOR J=-Aux TO Aux
1520     Xy(2,I)=Xy(2,I)+Xy(1,I+J)
1530     NEXT J
1540    Xy(2,I)=Xy(2,I)/Avechannel
1550    NEXT I
1560    !
1570    FOR I=256-Aux TO 255
1580    Xy(2,I)=0
1590    NEXT I
1600   Mincounts=1000
1610    FOR I=Aux+3 TO Searchchannel
1620    Mincounts=MIN(Mincounts,Xy(2,I))
1630    IF Xy(2,I)=Mincounts THEN Startchannel=I-1
1640    NEXT I
1650   Startcounts=PROUND(Xy(2,Startchannel+1),-2)
1660   Peakcounts=1
1670    FOR I=Startchannel+3 TO 256-Aux
1680    Peakcounts=MAX(Peakcounts,Xy(2,I))
1690    IF Xy(2,I)=Peakcounts THEN Peakchannel=I-1
1700    NEXT I
1710   Endchannel=PROUND(Startchannel+2.5*(Peakchannel-Startchannel)+1,0)
1720   IF (Endchannel-Startchannel<10) OR (Peakcounts/Mincounts<1.1) THEN 5440
1730   IF Endchannel>255-Aux THEN Endchannel=254-Aux-2
1740   Endcounts=PROUND(Xy(2,Endchannel+1),-2)
1750   IF Endcounts<1 THEN Endcounts=1
1760   RETURN
1770   ! ------------------------------------------------------------------------
1780 Computeflow:  B0=Xy(2,254-Aux)
1790  IF Endcounts<2*B0 THEN B0=Endcounts/2
1800  B0=PROUND(B0,-2)
1810  Startcounts=PROUND(Startcounts,-2)
1820  B1=Startcounts
1830  B2=Endcounts
1840  T1=Startchannel*Deltatime-Deltatime/2
1850  T2=Endchannel*Deltatime-Deltatime/2
1860  IF (B2-B0=0) OR (T2-T1=0) THEN 1890
1870  Lambda=LOG((B1-B0)/(B2-B0))/(T2-T1)
1880  GOTO 1900
1890  Lambda=.05
1900  Ba=(B1-B0)*EXP(Lambda*T1)
1910  Ba=PROUND(Ba,-2)
1920  Lambda=PROUND(Lambda,-5)
1930   FOR I=1 TO 256
1940   IF (I<Startchannel+1) OR (I>Endchannel+1) THEN GOTO 1990
```

```
1950   Time=(I-1)*Deltatime-Deltatime/2
1960   Xy(3,I)=Xy(1,I)-B0-Ba*EXP(-Lambda*Time)          ! BACKGROUND CORRECTION
1970   Xy(3,I)=Xy(3,I)*EXP(Decayconstant*Time)             ! DECAY CORRECTION
1980   GOTO 2000
1990   Xy(3,I)=0
2000   NEXT I
2010   !
2020   FOR I=Peakchannel+1 TO Endchannel+1
2030   IF Xy(3,I)<0 THEN 2050
2040   NEXT I
2050  Limitchannel=I-1
2060   FOR I=Limitchannel+1 TO Endchannel+1
2070   Time=(I-1)*Deltatime-Deltatime/2
2080   Xy(3,I)=Xy(1,I)-B0-Ba*EXP(-Lambda*Time)          ! BACKGROUND CORRECTION
2090   Xy(3,I)=Xy(3,I)*EXP(Decayconstant*Time)             ! DECAY CORRECTION
2100   NEXT I
2110  Numerator=0
2120  Denominator=0
2130   FOR I=Startchannel+1 TO Endchannel+1
2140   Time=(I-1)*Deltatime-Deltatime/2
2150   Numerator=Numerator+Xy(3,I)/Time^Timexponent
2160   Denominator=Denominator+Xy(3,I)/Time^(Timexponent-1)
2170   NEXT I
2180  Inversetime=Numerator/Denominator
2190  Flowvelocity=PROUND(Spacing*Inversetime,-3)
2200  RETURN
2210  ! ------------------------------------------------------------------------
2220 Plots: PLOTTER IS "GRAPHICS"
2230  GRAPHICS
2240  GCLEAR
2250  Maxy=1
2260   FOR I=1 TO 256
2270   IF Maxy<Xy(1,I) THEN Maxy=Xy(1,I)
2280   NEXT I
2290  Ly=LGT(Maxy)
2300  Testy=FRACT(Ly)+(Ly<0)
2310  Ytic=10^(INT(Ly)-1)*(1+1.5*((Testy).39794) AND (Testy<.69897))+4*((Testy>=
.69897) AND (Testy<=.87506))+6.5*(Testy).87506))
2320  LOCATE 20,123,15,95
2330  SCALE 0,257,0,1.05*Maxy
2340  AXES 25,Ytic,0,0
2350  CSIZE 3
2360  LDIR 90
2370  LORG 8
2380   FOR I=0 TO 250 STEP 25
2390   MOVE I,-.01*Maxy
2400   LABEL I
2410   NEXT I
2420  LDIR 0
2430  LORG 8
2440   FOR I=0 TO 1.05*Maxy STEP Ytic
2450   MOVE -5,I
2460   LABEL I
2470   NEXT I
2480  MOVE 0,Xy(1,2)
2490  DRAW 1.5,Xy(1,2)
2500   FOR I=2 TO 255
2510   DRAW I-.5,Xy(1,I+1)
2520   DRAW I+.5,Xy(1,I+1)
2530   NEXT I
2540   SETGU
2550   MOVE 5,50
2560   LORG 5
2570   LDIR 90
2580   LABEL "COUNTS/CHANNEL"
2590   MOVE 70,1
```

```
2600   LORG 4
2610   LDIR 0
2620   LABEL "TIME CHANNEL"
2630   MOVE 100,90
2640   LORG 5
2650   LDIR 0
2660   CSIZE 6,1
2670   LABEL Runnumber$
2680   DUMP GRAPHICS
2690   EXIT GRAPHICS
2700   RETURN
```

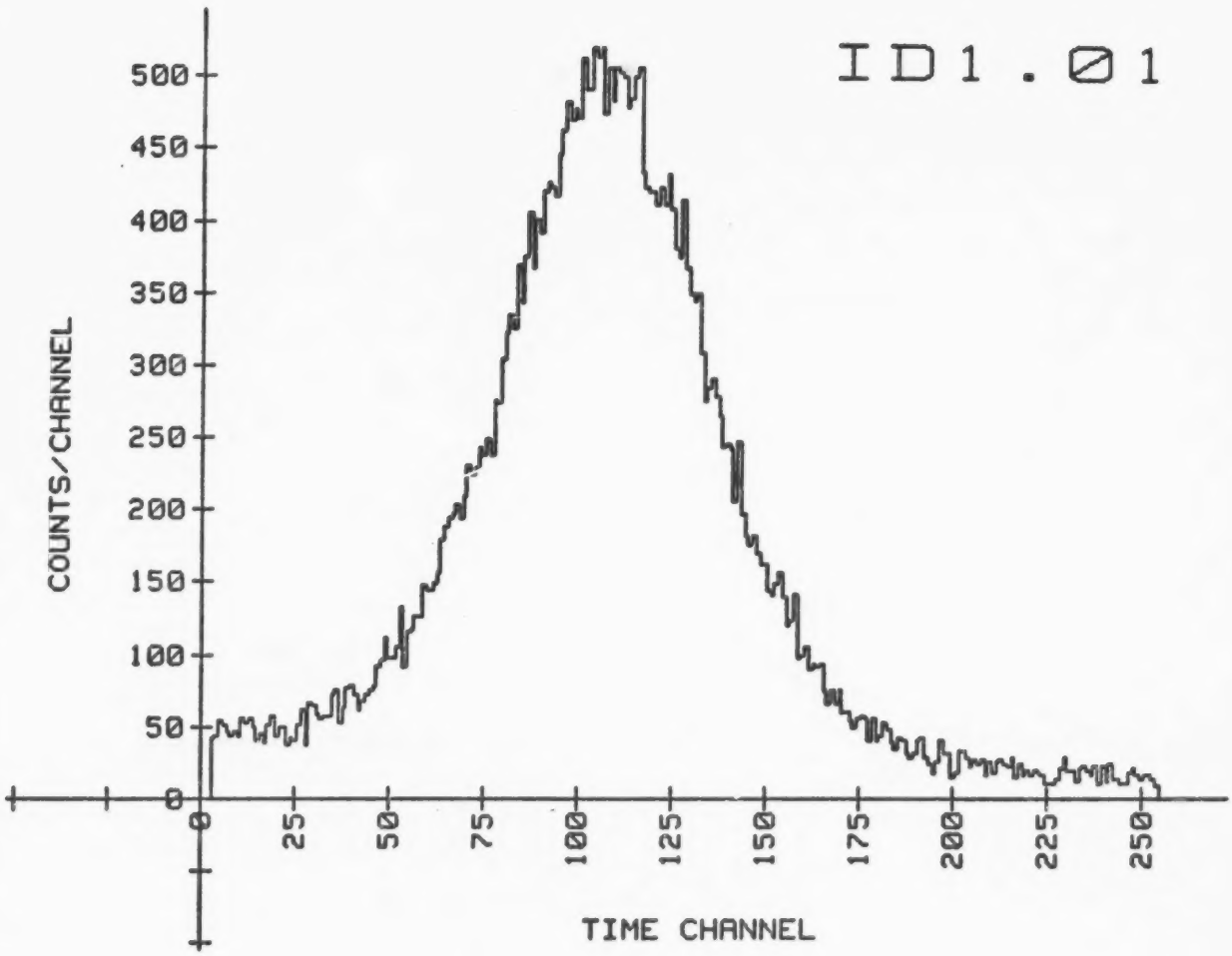
Appendix B

Test Data, Test ID1

RUN NUMBER = ID1.01

0	0	0	0	42	43	54	51	47
8	43	47	43	56	53	55	50	41
16	45	39	51	57	43	50	49	38
24	42	41	51	62	37	66	65	59
32	55	57	58	73	76	53	64	77
40	79	73	62	68	72	76	79	92
48	97	111	98	98	105	133	92	116
56	118	126	127	147	145	145	149	157
64	180	188	194	198	204	194	210	230
72	225	229	242	238	249	238	276	275
80	305	322	335	326	369	344	376	406
88	367	401	392	420	427	423	418	446
96	462	483	470	478	472	512	491	492
104	520	514	520	474	506	484	506	503
112	500	479	485	500	507	434	424	421
120	421	412	423	411	432	409	382	376
128	414	368	349	345	349	309	276	285
136	291	279	265	244	245	242	206	247
144	197	183	176	183	171	162	163	144
152	142	149	156	140	120	124	141	98
160	100	105	91	93	92	93	76	66
168	76	66	75	61	61	54	49	55
176	58	56	40	55	41	44	53	48
184	39	34	42	40	32	29	31	41
192	42	29	24	18	25	40	31	31
200	15	18	33	33	28	23	27	24
208	27	17	25	18	26	27	24	22
216	29	15	24	17	19	17	19	18
224	16	11	11	10	13	21	28	20
232	20	12	21	23	20	17	22	11
240	23	12	24	14	14	11	11	18
248	21	17	13	17	16	13	9	0

SPACING = 1.105
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 247
START COUNTS = 43.55
END COUNTS = 16
CONSTANT BACKGROUND = 8
DECAYING BACKGROUND = 37.02
DECAY CONSTANT OF BACKGROUND = .06215
NEUTRON MONITOR = 1.1457
FLOW VELOCITY =(.899)



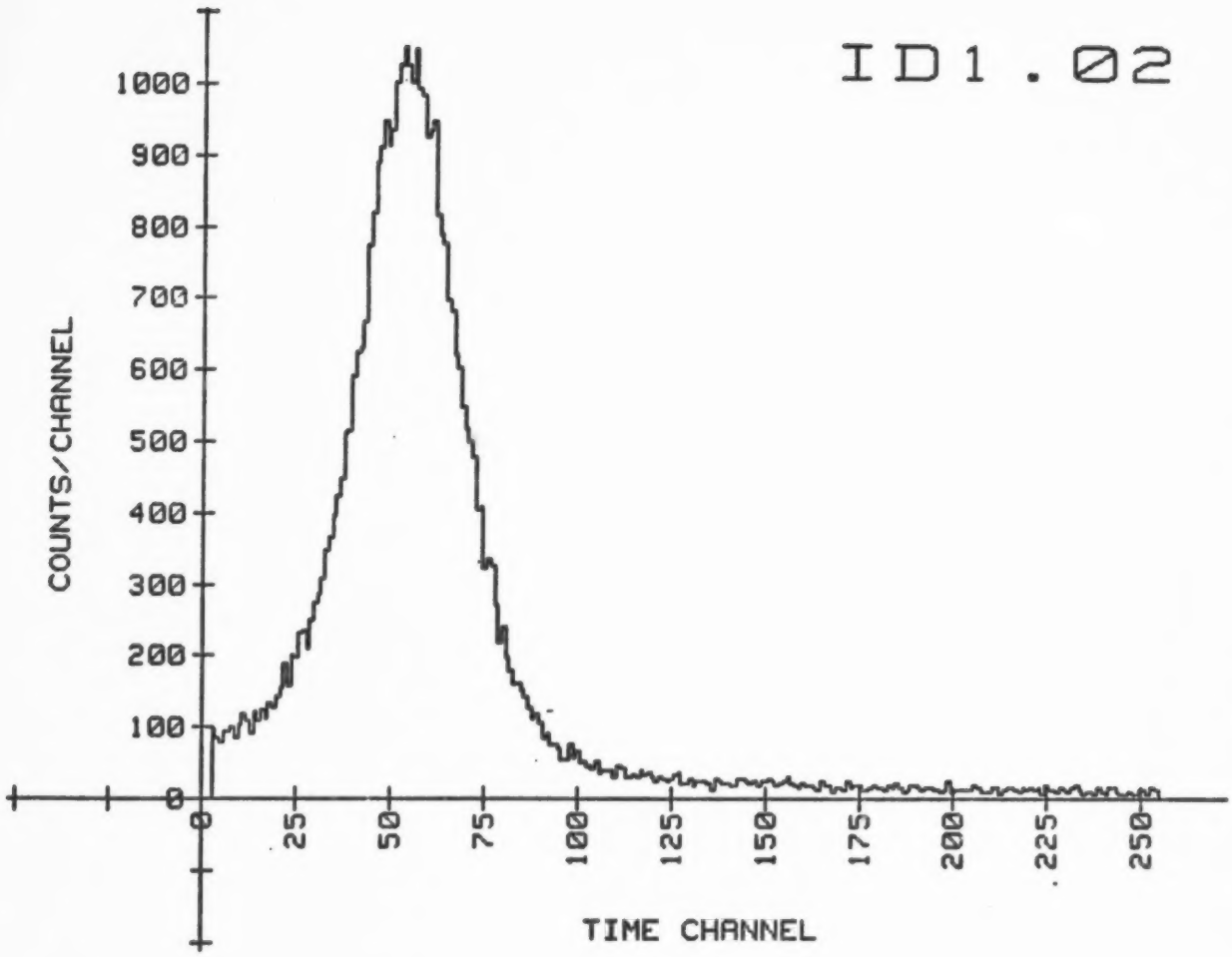
THE PEAK OF THE DISTRIBUTION IS IN TIME CHANNEL 106
THIS IS OUTSIDE OF THE SPECIFIED LIMITS, 50 - 100,
AND THE ACCURACY OF THE TEST RESULT IS THEREBY REDUCED.

PLEASE CORRECT THE LENGTH OF THE TIME CHANNELS OF THE MULTISCALER
BEFORE THE NEXT TEST.

RUN NUMBER = ID1.02

0	0	0	0	97	84	78	96	94
8	102	86	104	120	110	91	121	109
16	126	114	133	128	142	156	188	158
24	201	198	232	235	211	250	274	287
32	308	349	367	395	424	449	511	514
40	591	624	632	668	774	821	889	911
48	948	915	935	1003	1026	1052	1027	1002
56	1048	995	985	926	937	948	818	791
64	776	697	682	623	605	549	518	501
72	478	406	410	322	335	327	272	221
80	242	199	179	161	163	153	143	128
88	114	120	106	85	91	77	75	69
96	54	55	75	58	68	52	51	45
104	44	53	37	41	41	39	31	47
112	43	31	30	32	29	41	32	37
120	31	24	30	26	23	26	34	38
128	20	21	28	17	25	23	25	20
136	12	27	23	22	20	17	18	26
144	27	25	22	24	18	23	23	27
152	25	19	20	25	30	21	19	15
160	21	18	18	15	13	23	18	18
168	9	15	16	13	23	15	18	19
176	13	12	14	19	14	14	11	18
184	14	20	15	10	12	17	19	15
192	12	15	16	12	13	10	12	23
200	10	11	11	12	12	11	17	14
208	10	9	10	15	14	5	11	14
216	15	13	10	14	12	16	13	15
224	7	10	13	11	8	15	13	10
232	16	17	13	7	10	9	7	14
240	9	7	15	14	10	5	7	10
248	8	5	12	11	6	15	12	0

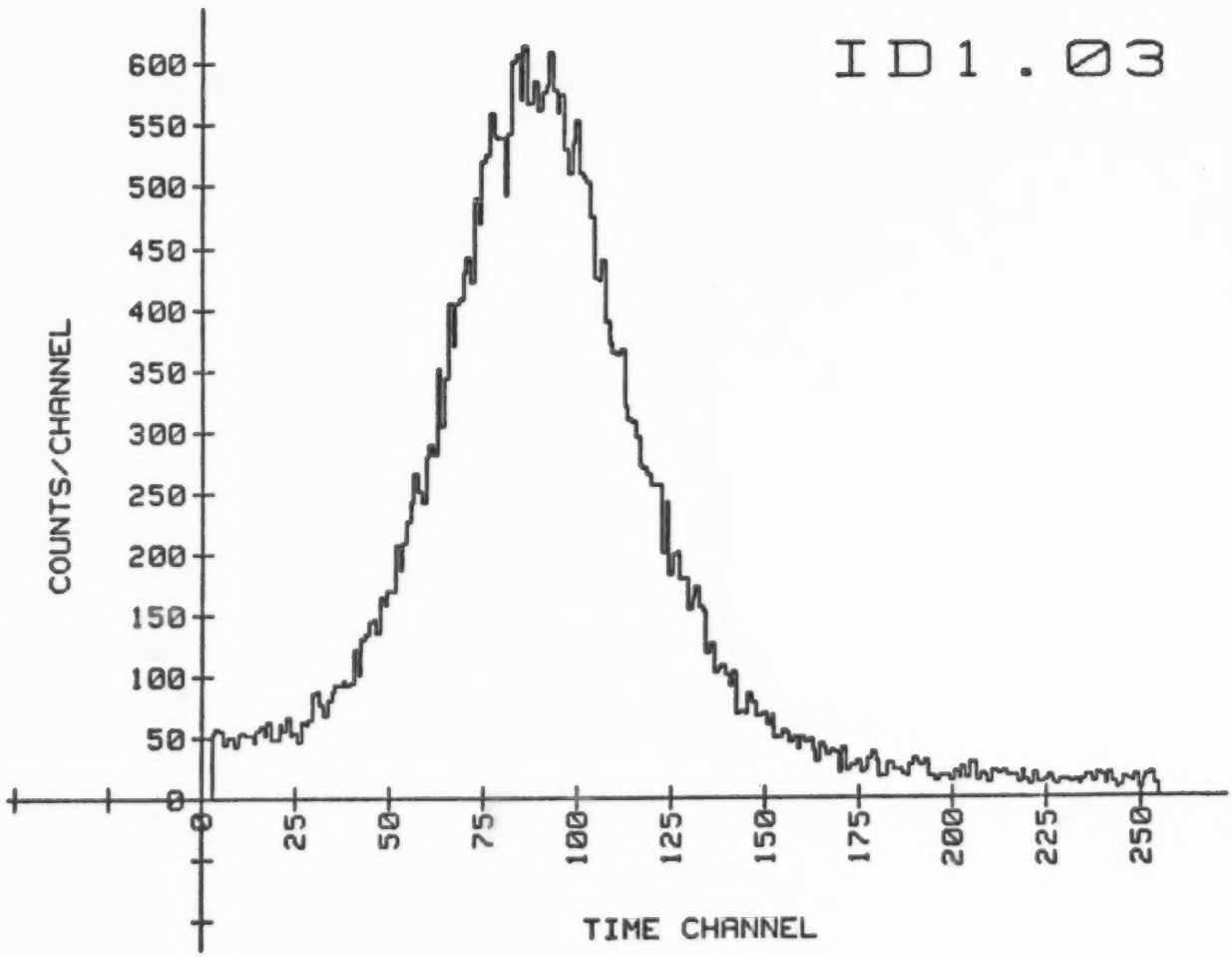
SPACING = 1.105
DELTA TIME = .2
START CHANNEL = 7
END CHANNEL = 131
START COUNTS = 88.27
END COUNTS = 23.91
CONSTANT BACKGROUND = 9.32
DECAYING BACKGROUND = 86.26
DECAY CONSTANT OF BACKGROUND = .06808
NEUTRON MONITOR = 1.1501
FLOW VELOCITY = .097


ID1.02
COUNTS/CHANNEL
1000
900
800
700
600
500
400
300
200
100
0
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

RUN NUMBER = ID1.03

0	0	0	0	54	57	55	45	50
8	50	43	52	54	52	52	47	55
16	58	51	62	49	48	60	56	66
24	51	53	46	62	60	64	85	87
32	77	68	81	88	93	92	96	93
40	95	121	102	130	133	144	147	136
48	164	159	170	170	206	187	209	227
56	243	265	252	243	280	288	282	352
64	304	344	404	370	405	408	429	442
72	422	491	471	521	526	560	541	540
80	540	494	543	602	608	573	615	568
88	569	587	564	578	583	609	579	561
96	575	532	512	536	555	511	508	504
104	475	426	424	441	391	372	366	364
112	368	321	310	308	296	272	271	266
120	257	257	257	202	242	183	200	201
128	180	180	155	164	173	156	153	120
136	126	104	107	109	101	93	103	70
144	72	70	85	78	67	67	70	61
152	68	50	50	55	53	47	50	41
160	50	46	49	39	30	44	41	36
168	39	37	22	41	24	26	26	31
176	21	23	32	37	31	17	17	28
184	28	24	24	20	17	27	32	28
192	26	31	18	18	14	17	18	18
200	15	22	16	25	16	29	29	15
208	19	18	13	22	21	19	22	18
216	18	18	13	21	14	11	19	13
224	13	15	17	13	11	15	14	14
232	12	14	10	15	17	18	12	19
240	10	11	20	12	8	9	16	15
248	13	10	7	14	17	19	10	0

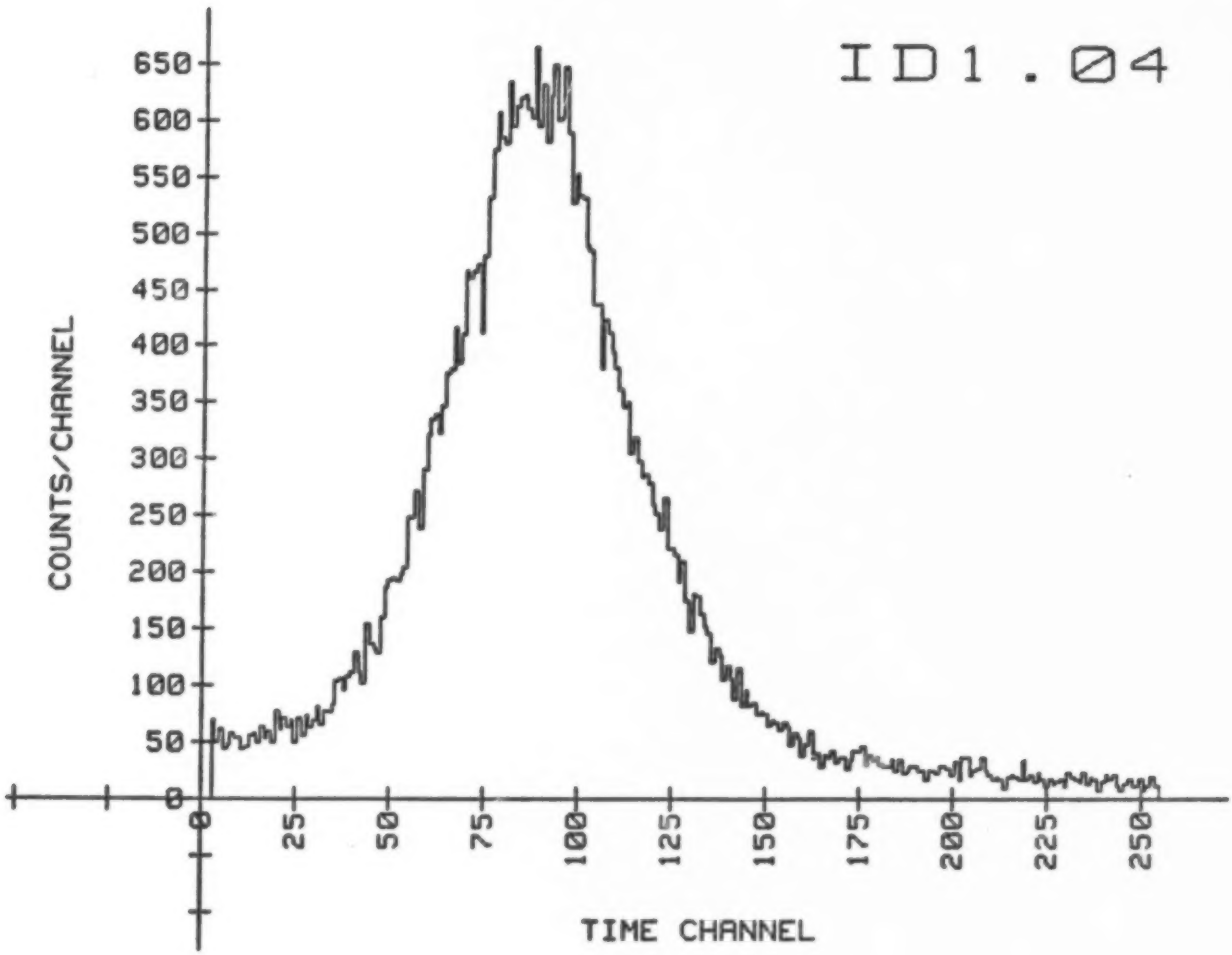
SPACING = 1.105
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 211
START COUNTS = 46.55
END COUNTS = 19.45
CONSTANT BACKGROUND = 9.73
DECAYING BACKGROUND = 38.42
DECAY CONSTANT OF BACKGROUND = .06529
NEUTRON MONITOR = 1.1768
FLOW VELOCITY = .119


ID1.03
COUNTS/CHANNEL
600
550
500
450
400
350
300
250
200
150
100
50
0
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

RUN NUMBER = ID1.04

0	0	0	0	69	50	61	44	49
8	58	54	54	44	47	55	57	51
16	63	53	60	51	77	62	72	64
24	70	51	71	55	73	63	69	81
32	65	77	78	82	105	106	96	107
40	111	129	112	103	154	136	133	129
48	159	186	192	194	192	199	205	249
56	249	272	239	291	321	335	339	324
64	347	376	380	417	385	411	466	460
72	467	473	413	479	531	574	608	586
80	580	634	596	612	621	622	610	604
88	665	596	632	582	623	650	601	604
96	647	589	528	554	534	531	490	486
104	437	438	382	424	413	396	381	362
112	347	350	306	320	298	286	287	279
120	261	252	239	265	222	221	216	193
128	211	175	149	181	179	163	153	146
136	121	133	128	106	117	106	89	116
144	83	97	82	84	76	77	75	65
152	69	67	62	68	63	48	58	53
160	39	48	59	37	40	29	39	37
168	43	32	36	36	27	34	43	42
176	46	31	38	35	37	31	28	29
184	34	26	35	24	25	29	28	26
192	26	18	25	25	24	29	28	27
200	21	32	17	37	37	21	26	27
208	37	26	22	17	20	17	10	20
216	22	20	18	34	17	21	15	23
224	18	12	17	13	16	17	12	23
232	20	18	16	24	14	19	17	8
240	15	22	18	22	11	8	14	18
248	11	12	18	7	11	20	11	0

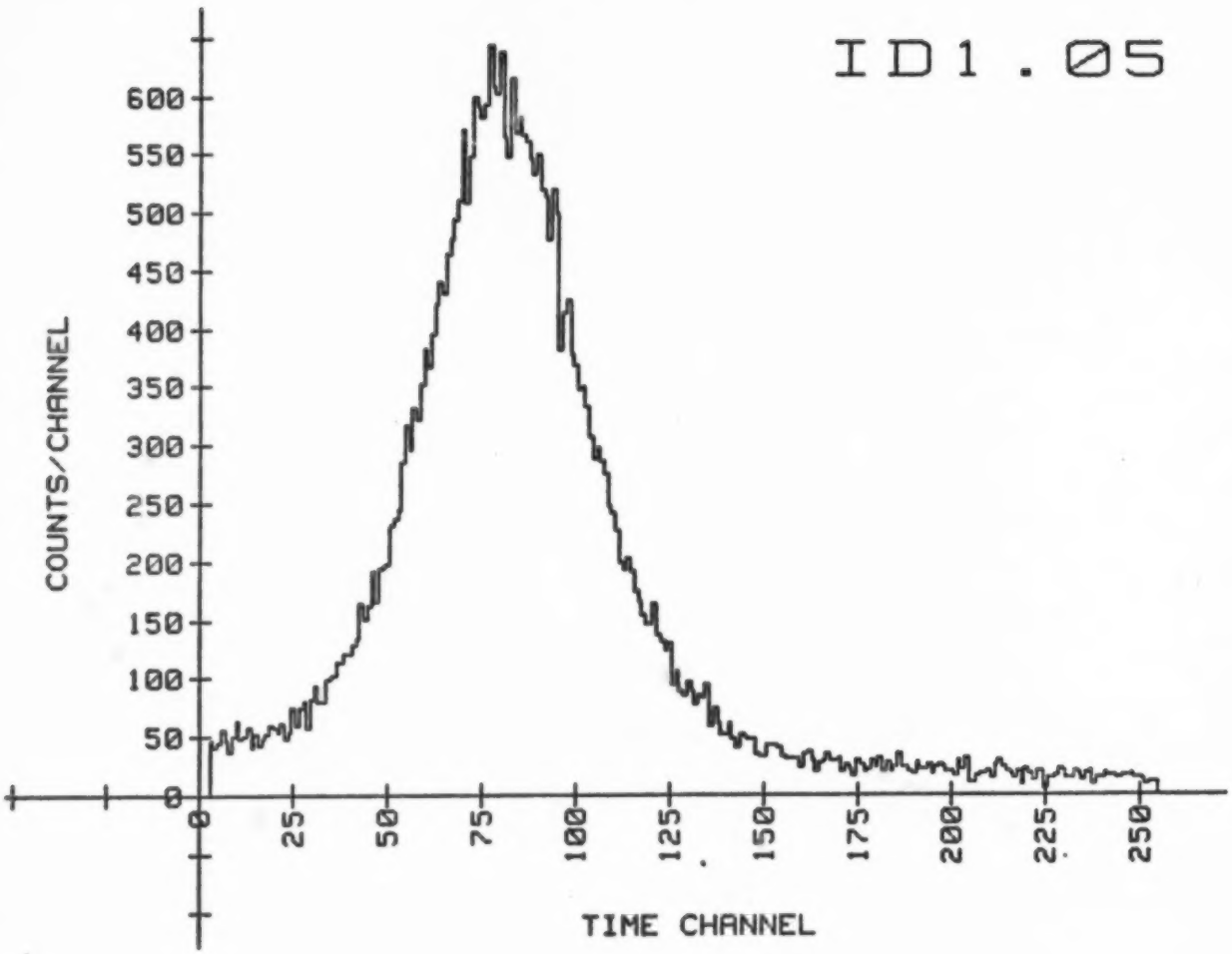
SPACING = 1.105
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 211
START COUNTS = 48.18
END COUNTS = 22.18
CONSTANT BACKGROUND = 11.09
DECAYING BACKGROUND = 38.54
DECAY CONSTANT OF BACKGROUND = .05918
NEUTRON MONITOR = 1.2037
FLOW VELOCITY = .119


ID1.04
COUNTS/CHANNEL
650
600
550
500
450
400
350
300
250
200
150
100
50
0
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

RUN NUMBER = ID1.05

0	0	0	0	47	41	45	56	46
8	38	51	63	49	51	57	41	52
16	43	48	52	59	57	54	62	49
24	55	74	59	74	80	58	83	93
32	81	80	99	101	103	113	113	121
40	122	129	134	164	152	162	192	167
48	194	196	197	232	237	245	285	317
56	296	333	323	353	382	367	396	422
64	441	431	465	478	494	511	572	509
72	548	599	591	582	594	644	609	603
80	639	565	548	615	570	582	567	562
88	547	534	551	520	515	478	521	501
96	382	414	426	378	369	349	350	334
104	308	290	299	287	277	248	242	228
112	199	195	203	193	176	167	154	148
120	147	165	139	132	125	130	95	106
128	90	86	97	89	78	85	84	95
136	59	75	61	52	53	61	49	41
144	52	51	48	49	35	33	33	43
152	43	43	41	33	31	31	31	32
160	24	36	37	29	20	28	30	36
168	30	29	31	20	26	23	16	30
176	26	21	23	30	25	31	21	28
184	21	25	36	24	24	20	18	28
192	23	22	26	18	24	27	24	20
200	21	16	30	23	31	12	12	17
208	18	19	20	15	27	30	24	20
216	19	14	21	9	22	19	13	20
224	20	6	14	15	16	22	20	14
232	15	21	18	13	18	20	9	15
240	14	19	16	16	15	15	16	17
248	19	14	14	13	10	12	11	0

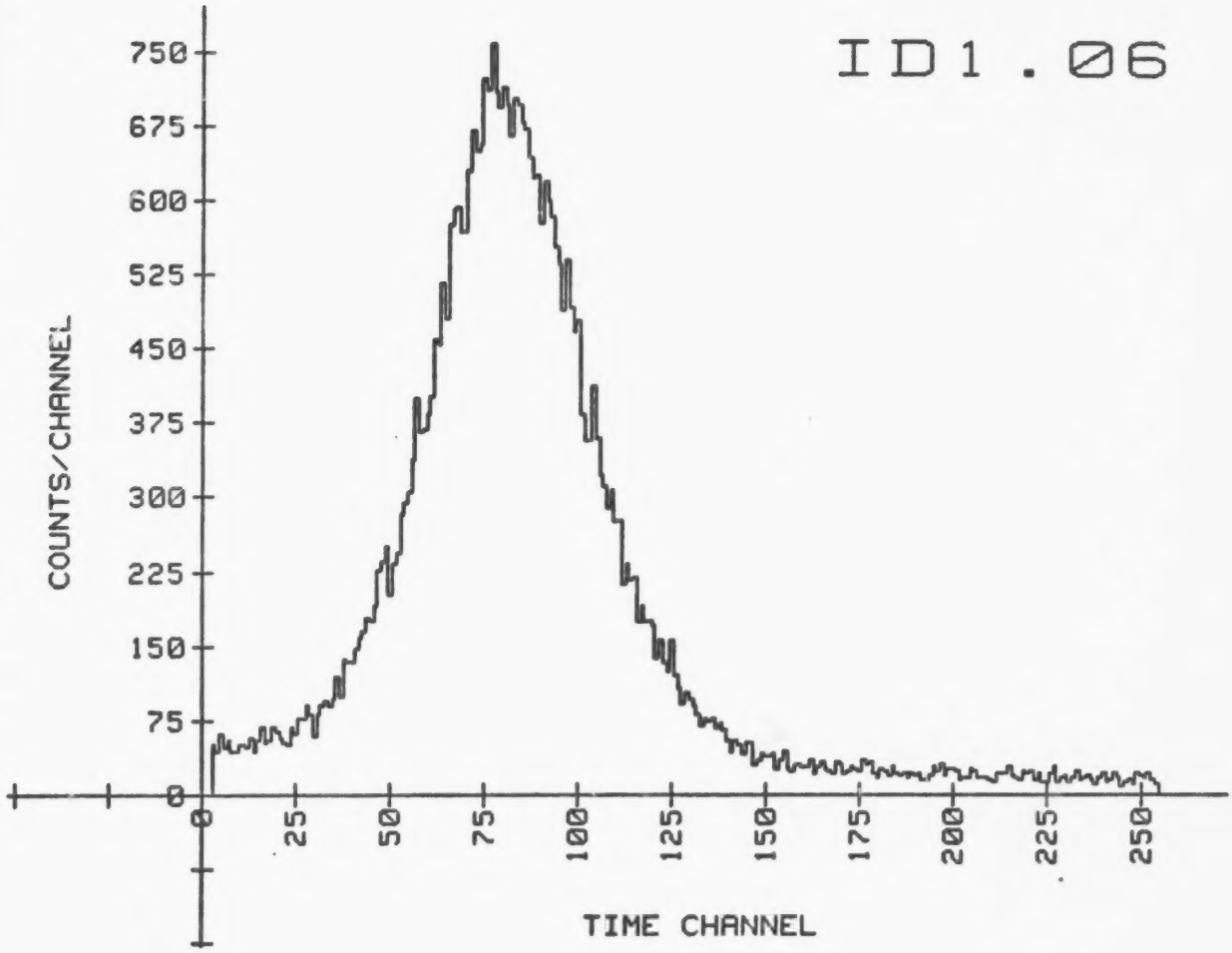
SPACING = 1.105
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 186
START COUNTS = 44.27
END COUNTS = 25.09
CONSTANT BACKGROUND = 12.55
DECAYING BACKGROUND = 32.81
DECAY CONSTANT OF BACKGROUND = .05184
NEUTRON MONITOR = 1.1241
FLOW VELOCITY = .133


ID1.05
COUNTS/CHANNEL
600
550
500
450
400
350
300
250
200
150
100
50
0
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

RUN NUMBER = ID1.06

0	0	0	0	50	43	62	48	54
8	45	43	51	50	48	58	43	55
16	69	53	54	68	63	57	52	50
24	67	62	76	77	90	82	59	81
32	91	95	91	97	119	99	136	134
40	133	148	158	164	179	176	191	226
48	234	252	202	232	243	283	294	305
56	339	399	366	370	386	401	460	454
64	517	480	575	592	594	570	570	630
72	671	651	656	722	711	758	709	695
80	715	697	665	703	696	679	673	644
88	623	627	577	620	599	584	554	536
96	490	540	492	467	478	384	359	359
104	414	361	323	313	290	307	277	277
112	214	233	217	219	176	191	176	176
120	172	138	156	133	125	155	120	107
128	93	104	96	89	82	70	77	74
136	77	67	72	65	54	45	55	51
144	42	53	52	30	35	42	40	40
152	42	26	36	43	26	24	31	31
160	29	28	35	23	28	32	26	25
168	23	32	30	22	24	29	26	24
176	36	31	33	23	18	27	25	19
184	29	22	20	22	17	22	19	23
192	16	16	19	29	24	31	20	27
200	27	25	15	17	18	27	24	17
208	18	17	15	13	22	23	22	28
216	20	18	15	25	22	24	15	22
224	13	14	21	28	13	17	20	13
232	17	24	16	17	20	15	10	17
240	21	14	16	23	18	9	13	15
248	11	21	19	17	23	16	12	0

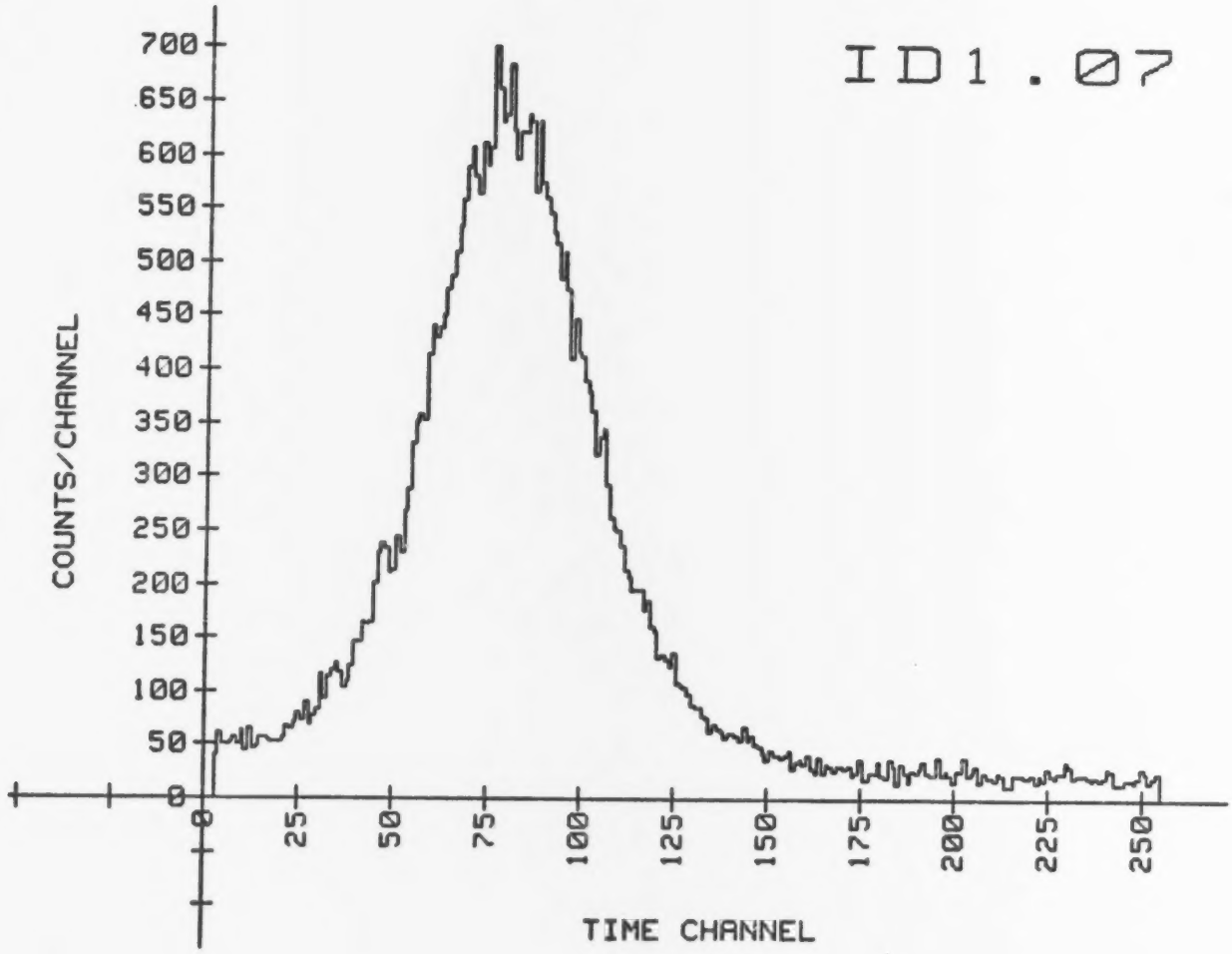
SPACING = 1.105
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 191
START COUNTS = 44.91
END COUNTS = 20.64
CONSTANT BACKGROUND = 10.32
DECAYING BACKGROUND = 36.1
DECAY CONSTANT OF BACKGROUND = .06573
NEUTRON MONITOR = 1.2334
FLOW VELOCITY = .132


ID1.06
750
675
600
525
450
375
300
225
150
75
0
COUNTS/CHANNEL
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

RUN NUMBER = ID1.07

0	0	0	0	40	61	50	50	53
8	56	50	63	45	65	47	49	56
16	57	54	52	53	52	57	67	65
24	71	80	73	89	70	77	83	115
32	93	114	120	125	118	104	109	123
40	146	146	164	162	164	201	229	238
48	234	211	213	243	229	268	289	331
56	351	358	353	415	441	431	439	450
64	475	488	510	534	558	590	608	581
72	565	612	592	608	701	662	632	637
80	685	624	598	622	621	638	631	567
88	631	574	561	547	528	518	486	510
96	475	411	447	417	413	391	380	362
104	320	338	345	293	263	252	250	235
112	214	207	195	196	195	177	184	160
120	157	132	135	131	124	136	108	106
128	104	98	87	86	85	77	75	63
136	69	66	62	56	61	61	59	54
144	67	55	58	51	49	43	36	44
152	40	40	39	40	45	29	35	36
160	32	40	28	24	38	24	32	30
168	26	31	31	29	30	23	25	37
176	19	18	25	24	35	23	20	36
184	30	15	33	25	16	27	25	29
192	35	25	22	22	38	22	26	22
200	17	27	27	39	22	25	30	16
208	24	21	20	19	24	22	12	13
216	23	22	23	21	21	23	16	23
224	19	28	22	21	25	25	35	30
232	21	23	22	22	20	18	21	19
240	21	29	26	14	14	15	18	18
248	16	21	28	24	16	20	24	0

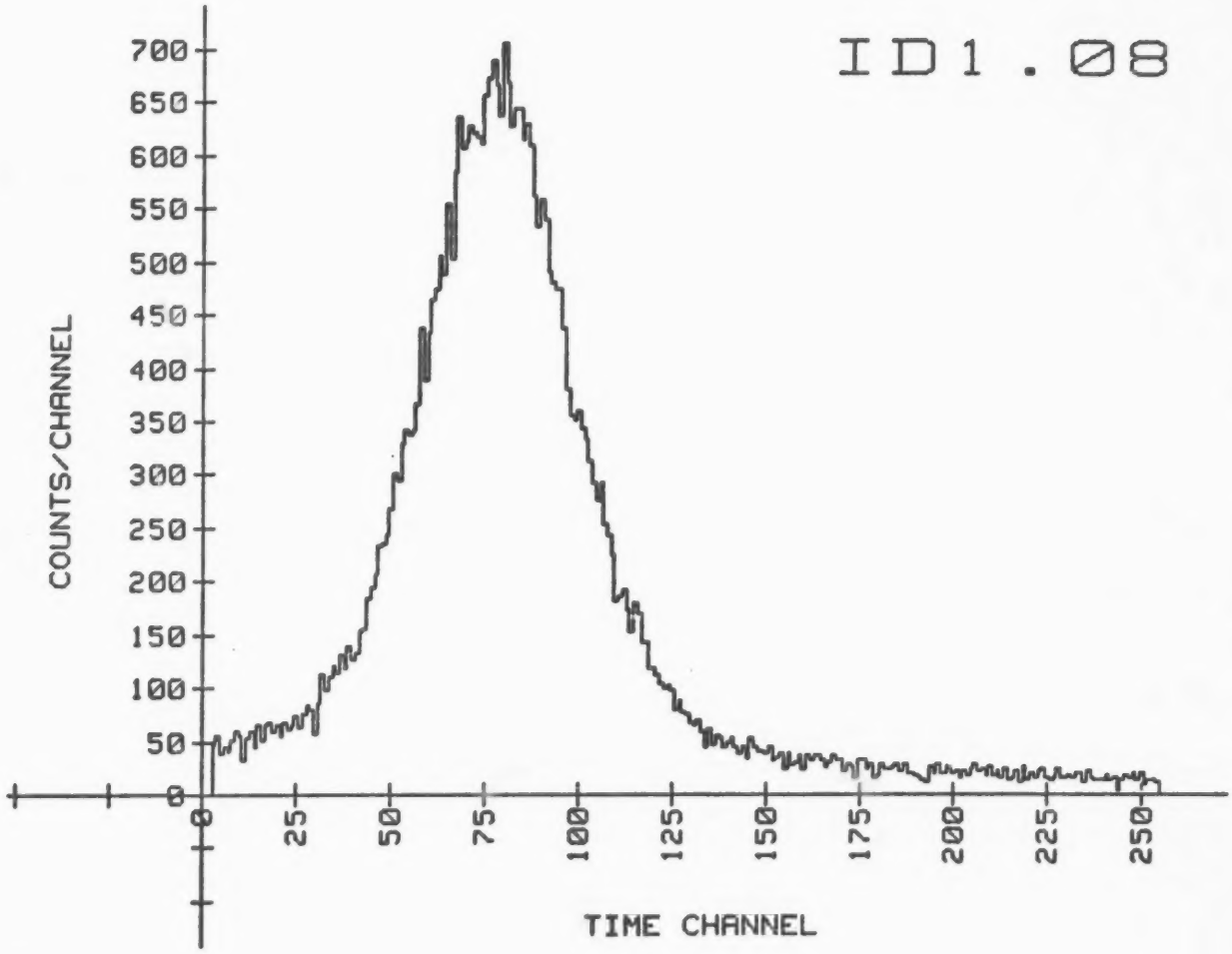
SPACING = 1.101
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 193
START COUNTS = 48.45
END COUNTS = 26.09
CONSTANT BACKGROUND = 13.05
DECAYING BACKGROUND = 36.66
DECAY CONSTANT OF BACKGROUND = .05369
NEUTRON MONITOR = 1.1997
FLOW VELOCITY = .134


ID1.07
COUNTS/CHANNEL
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

RUN NUMBER = ID1.08

0	0	0	0	47	56	38	44	40
8	52	60	56	32	53	60	46	66
16	52	65	67	60	66	55	67	62
24	66	74	64	76	83	79	58	86
32	113	98	111	120	114	130	119	140
40	127	132	154	155	184	194	206	233
48	236	243	269	301	295	329	342	338
56	342	367	437	389	434	465	474	505
64	490	554	504	585	637	608	614	629
72	623	617	611	657	673	689	668	638
80	706	669	628	645	645	615	630	609
88	563	534	559	540	492	480	474	475
96	438	381	355	351	360	343	334	313
104	292	276	293	253	243	226	183	187
112	192	173	153	180	169	144	144	118
120	118	113	104	100	102	98	80	87
128	77	75	67	66	70	59	44	61
136	48	55	53	46	49	54	44	39
144	46	35	53	46	40	41	39	46
152	33	35	39	25	39	29	30	36
160	25	37	32	37	36	33	26	31
168	36	33	32	22	28	27	17	33
176	32	25	28	17	18	29	24	25
184	27	28	22	28	20	20	18	16
192	15	13	27	20	28	20	21	26
200	21	23	17	22	19	24	28	22
208	25	19	27	19	23	16	24	15
216	16	23	13	26	14	20	17	22
224	25	17	15	17	25	16	16	18
232	17	20	20	13	22	17	15	15
240	14	19	14	17	5	15	19	16
248	20	15	21	11	15	14	12	0

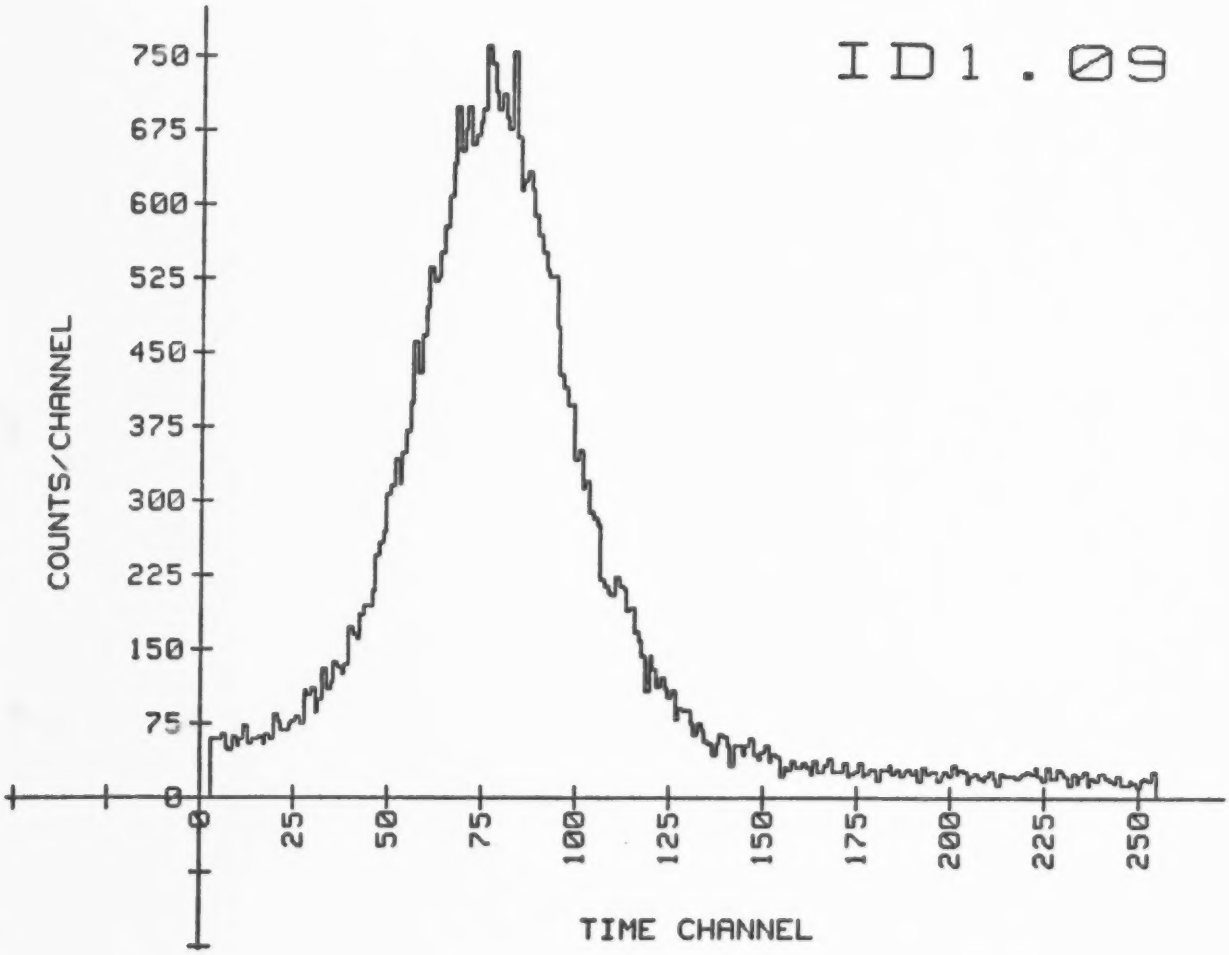
SPACING = 1.101
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 191
START COUNTS = 43.45
END COUNTS = 20.64
CONSTANT BACKGROUND = 10.32
DECAYING BACKGROUND = 34.52
DECAY CONSTANT OF BACKGROUND = .06339
NEUTRON MONITOR = 1.1868
FLOW VELOCITY = .136


ID1.08
COUNTS/CHANNEL
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

RUN NUMBER = ID1.09

0	0	0	0	60	59	59	65	50
8	49	62	52	59	72	56	59	59
16	62	56	63	59	83	78	69	69
24	75	77	82	76	108	103	111	85
32	100	131	110	117	137	133	126	134
40	173	165	162	185	195	193	209	244
48	258	269	306	316	342	317	348	371
56	399	461	429	468	497	535	523	528
64	552	578	608	642	699	654	677	699
72	662	670	684	698	761	744	714	697
80	713	689	676	755	669	615	624	634
88	616	589	570	551	533	527	528	476
96	427	415	396	396	341	350	314	320
104	289	283	275	220	214	207	204	222
112	213	212	190	192	167	159	143	108
120	144	131	113	122	110	101	109	79
128	91	89	88	74	65	76	69	58
136	56	45	56	63	62	53	33	53
144	54	44	54	60	45	40	47	52
152	38	44	41	23	30	28	37	30
160	31	36	31	24	38	27	26	33
168	40	27	26	27	35	21	24	27
176	35	21	24	29	28	17	29	28
184	33	24	29	22	26	28	25	28
192	18	30	24	27	26	17	22	26
200	22	33	24	28	27	16	21	24
208	20	17	22	26	20	13	25	23
216	22	23	20	23	24	27	24	31
224	22	17	30	19	20	28	26	21
232	13	24	16	21	26	14	19	17
240	24	24	19	18	15	22	13	13
248	17	15	10	17	19	17	26	0

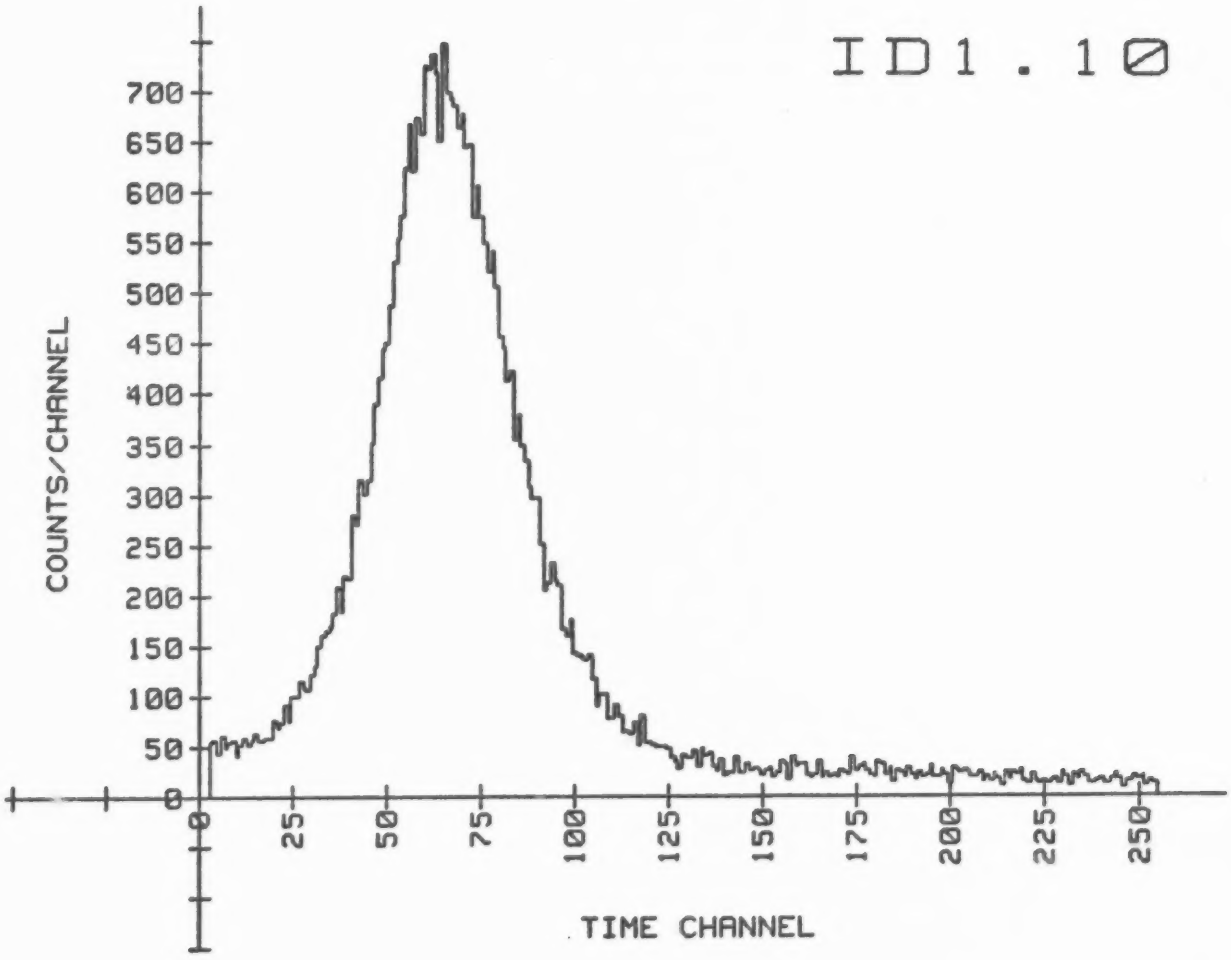
SPACING = 1.101
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 186
START COUNTS = 53.36
END COUNTS = 26.27
CONSTANT BACKGROUND = 13.14
DECAYING BACKGROUND = 41.89
DECAY CONSTANT OF BACKGROUND = .06254
NEUTRON MONITOR = 1.2533
FLOW VELOCITY = .138


ID1.09
COUNTS/CHANNEL
750
675
600
525
450
375
300
225
150
75
0
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

RUN NUMBER = ID1.10

0	0	0	0	55	56	44	61	49
8	55	57	41	51	58	53	56	62
16	57	56	58	59	76	69	74	90
24	75	100	100	114	108	106	121	131
32	150	160	164	170	183	208	184	218
40	216	279	271	314	301	314	351	391
48	416	444	451	487	532	554	576	625
56	667	623	674	659	726	725	736	719
64	653	748	700	694	688	666	679	647
72	648	576	606	577	551	523	542	508
80	458	447	415	422	355	380	349	333
88	307	296	297	252	205	212	231	215
96	211	166	160	175	142	141	139	137
104	141	117	91	102	101	78	77	91
112	81	66	66	63	73	51	80	55
120	55	52	50	49	49	47	39	35
128	28	41	40	40	45	31	48	41
136	44	31	27	37	21	23	24	39
144	24	24	32	27	28	26	22	27
152	28	20	23	34	33	17	39	30
160	32	32	22	20	21	35	20	23
168	20	22	20	25	23	22	38	26
176	30	33	25	21	20	34	33	21
184	28	16	25	24	20	28	22	18
192	24	19	22	30	20	20	25	21
200	14	28	26	24	26	23	19	20
208	24	15	20	16	22	18	11	23
216	17	23	22	27	15	12	21	16
224	13	16	13	16	17	14	23	19
232	10	22	18	24	19	14	12	15
240	18	12	14	17	21	17	8	16
248	16	19	18	19	10	15	12	0

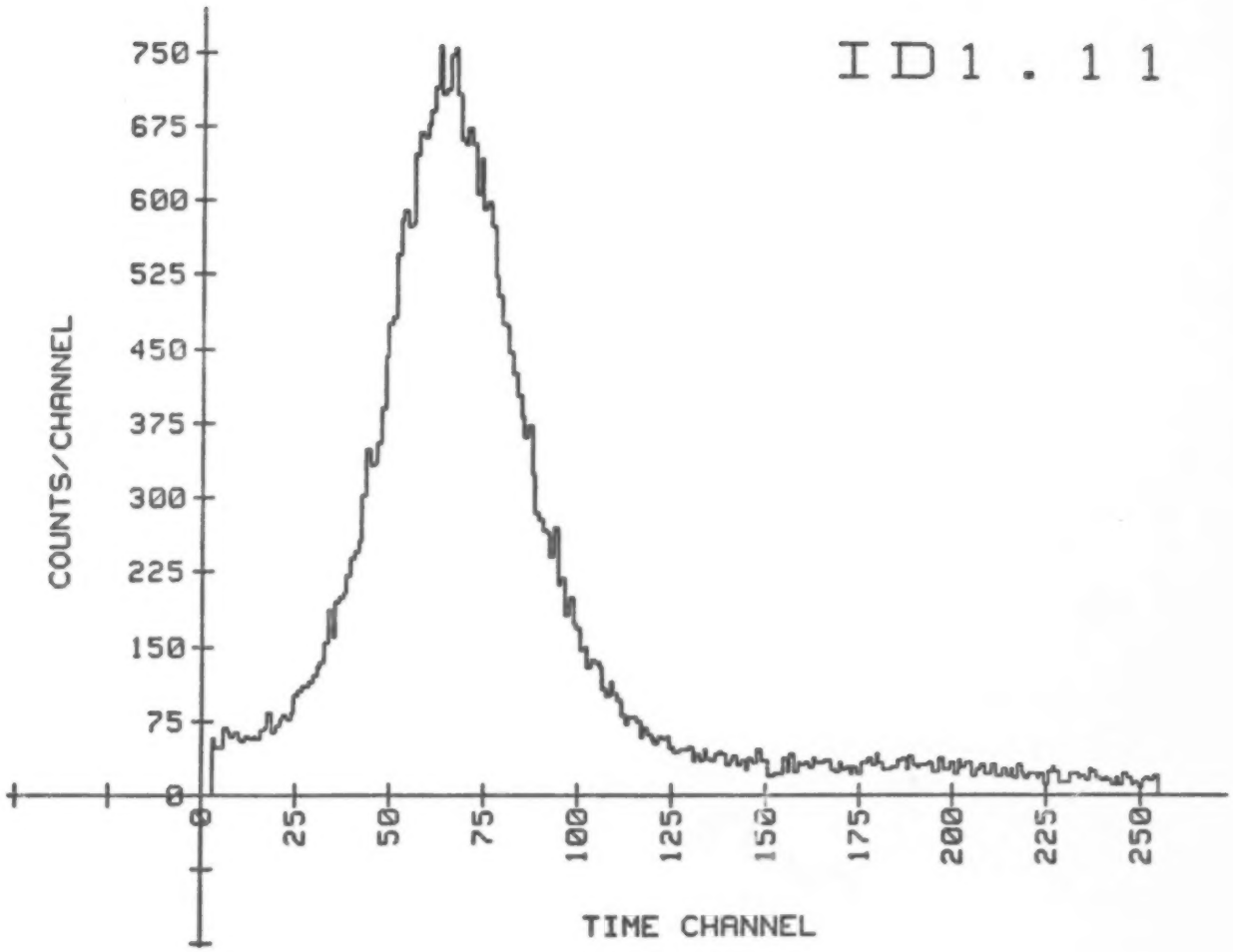
SPACING = 1.101
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 153
START COUNTS = 47.91
END COUNTS = 27
CONSTANT BACKGROUND = 13.5
DECAYING BACKGROUND = 35.87
DECAY CONSTANT OF BACKGROUND = .06409
NEUTRON MONITOR = 1.1348
FLOW VELOCITY = .164


ID1.10
COUNTS/CHANNEL
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

RUN NUMBER = ID1.11

0	0	0	0	57	48	49	68	64
8	60	63	57	55	60	56	60	58
16	66	69	84	64	71	76	80	77
24	84	100	105	109	110	115	121	130
32	134	154	187	159	195	200	204	222
40	238	245	256	302	348	332	335	354
48	390	442	475	481	546	581	589	574
56	576	647	668	664	678	690	714	756
64	707	712	748	754	708	661	657	672
72	658	607	641	591	599	573	524	503
80	475	473	446	425	403	382	361	372
88	324	285	279	268	266	241	270	212
96	219	181	199	173	169	147	150	130
104	136	133	129	107	101	114	104	96
112	82	73	79	79	74	59	68	62
120	57	52	60	57	60	49	44	43
128	46	47	48	36	42	35	46	38
136	34	42	43	41	31	35	40	31
144	36	27	38	32	47	36	35	20
152	21	21	22	37	24	42	25	33
160	30	32	29	38	32	32	35	34
168	27	25	33	27	29	22	28	22
176	33	32	37	31	41	32	26	27
184	28	29	35	37	26	40	30	28
192	31	30	32	25	24	38	26	26
200	33	21	35	28	32	33	19	26
208	31	22	22	30	20	20	27	19
216	26	18	31	22	17	22	22	17
224	21	12	23	28	25	13	14	14
232	21	22	18	20	15	26	25	18
240	15	17	16	12	17	10	22	18
248	12	14	9	15	18	15	19	0

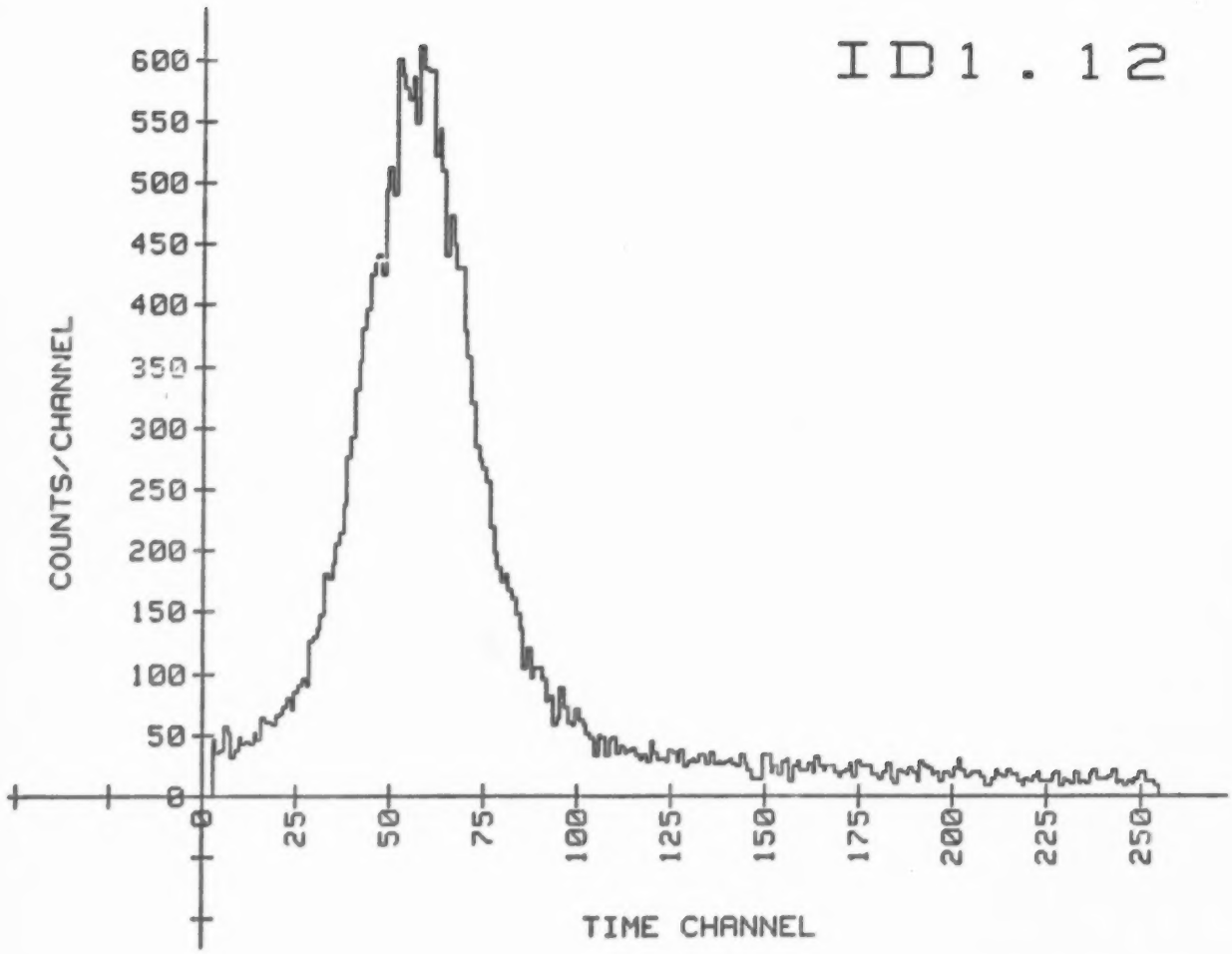
SPACING = 1.101
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 148
START COUNTS = 52.82
END COUNTS = 31.23
CONSTANT BACKGROUND = 14.73
DECAYING BACKGROUND = 39.59
DECAY CONSTANT OF BACKGROUND = .05933
NEUTRON MONITOR = 1.1575
FLOW VELOCITY = .162


ID1.11
750
675
600
525
450
375
300
225
150
75
0
COUNTS/CHANNEL
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

RUN NUMBER = ID1.12

0	0	0	0	46	36	38	56	52
8	32	38	48	43	45	43	51	46
16	64	60	60	58	66	68	73	79
24	71	85	90	96	91	126	129	136
32	148	181	177	190	205	214	237	276
40	293	331	354	382	398	426	438	442
48	425	494	512	491	601	589	578	570
56	587	550	612	595	593	592	524	544
64	518	442	473	450	431	431	379	359
72	321	285	275	268	258	220	198	187
80	175	181	168	161	149	137	104	121
88	97	104	104	96	78	81	58	64
96	88	72	60	58	71	62	58	51
104	48	34	49	48	34	46	48	35
112	41	35	38	39	33	31	34	29
120	45	36	30	30	28	37	36	29
128	37	24	28	31	29	33	34	27
136	36	27	29	27	28	30	27	24
144	34	26	21	15	15	15	33	33
152	20	25	18	28	30	12	25	29
160	22	22	26	19	32	24	22	25
168	25	20	16	19	22	26	16	28
176	25	25	24	17	18	15	20	27
184	14	10	22	20	17	23	19	12
192	28	24	23	18	20	13	20	19
200	16	23	30	22	16	17	19	19
208	16	8	8	15	22	18	16	21
216	18	17	12	8	15	12	16	19
224	12	13	13	17	19	8	15	13
232	11	20	10	13	10	17	21	14
240	15	15	16	22	11	12	8	12
248	11	15	19	19	12	12	9	0

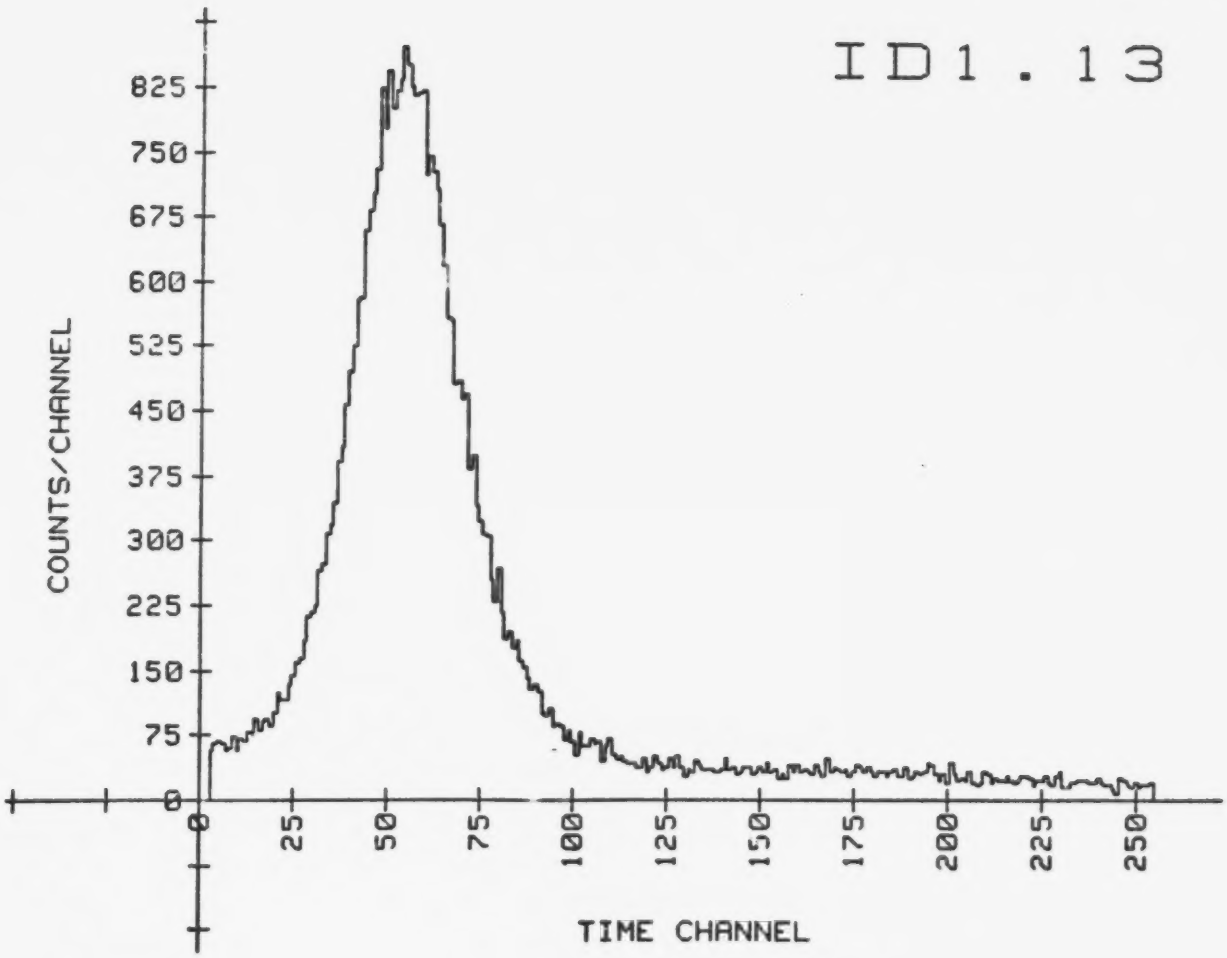
SPACING = 1.101
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 133
START COUNTS = 39.45
END COUNTS = 30.45
CONSTANT BACKGROUND = 13.91
DECAYING BACKGROUND = 26.12
DECAY CONSTANT OF BACKGROUND = .03448
NEUTRON MONITOR = .8595
FLOW VELOCITY = .191


ID1.12
COUNTS/CHANNEL
600
550
500
450
400
350
300
250
200
150
100
50
0
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

RUN NUMBER = ID1.13

0	0	0	0	58	65	69	66	57
8	60	73	59	71	68	78	76	94
16	82	90	93	86	100	125	117	117
24	133	143	159	165	184	213	217	225
32	266	273	309	320	344	391	410	459
40	496	525	579	581	661	683	703	730
48	826	780	846	802	823	836	873	853
56	827	818	820	822	726	747	728	709
64	667	620	558	557	482	485	466	470
72	384	399	342	325	308	305	256	230
80	267	218	187	194	176	184	163	155
88	142	130	133	126	101	98	105	86
96	88	86	71	82	69	54	79	62
104	63	71	66	60	46	62	72	52
112	47	51	46	42	43	38	38	49
120	34	37	51	42	35	37	49	39
128	51	39	29	36	34	46	41	36
136	36	36	32	32	36	49	35	39
144	31	33	38	39	30	33	39	33
152	43	32	36	25	31	25	40	33
160	40	33	35	32	31	41	34	27
168	48	34	39	36	33	35	27	33
176	40	39	32	39	32	27	34	32
184	29	33	36	28	29	39	26	29
192	32	30	33	43	40	31	24	30
200	19	43	31	24	26	22	33	19
208	18	20	34	30	19	26	23	22
216	27	22	21	23	28	27	26	18
224	24	24	28	21	18	27	33	16
232	15	20	19	24	23	24	19	20
240	25	19	17	18	13	9	25	22
248	18	15	21	16	17	18	20	0

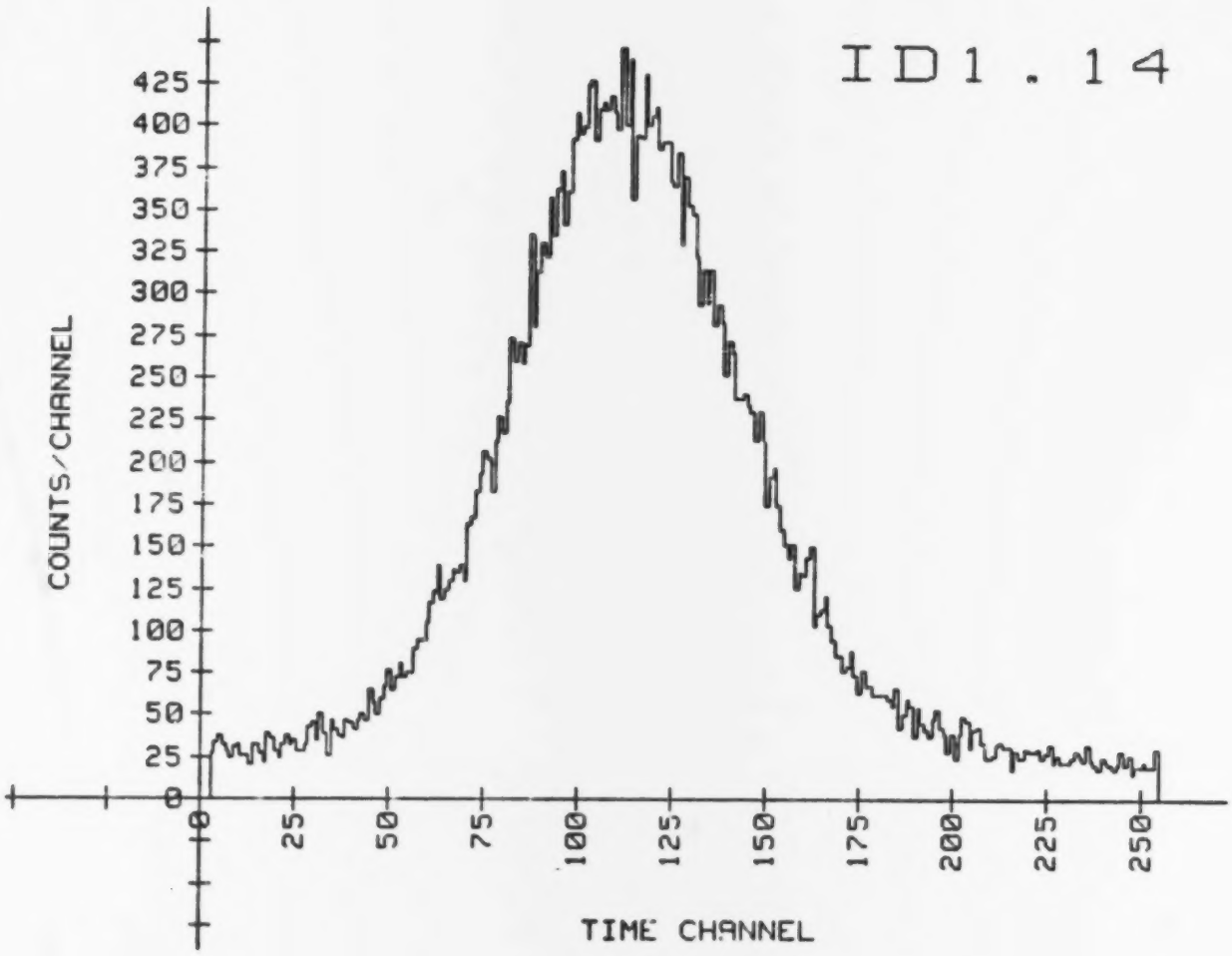
SPACING = 1.101
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 123
START COUNTS = 58.73
END COUNTS = 42
CONSTANT BACKGROUND = 17.36
DECAYING BACKGROUND = 42.59
DECAY CONSTANT OF BACKGROUND = .04467
NEUTRON MONITOR = 1.2262
FLOW VELOCITY = .199


ID1.13
COUNTS/CHANNEL
825
750
675
600
525
450
375
300
225
150
75
0
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

RUN NUMBER = ID1.14

0	0	0	0	27	34	37	32	29
8	25	31	32	26	26	21	32	33
16	27	22	39	36	28	25	33	37
24	33	35	29	29	32	43	45	35
32	50	39	26	46	41	38	36	46
40	45	41	46	51	47	65	57	51
48	59	67	76	65	73	80	72	75
56	75	90	94	95	105	116	123	139
64	119	125	130	136	135	139	130	163
72	167	183	193	206	202	183	213	227
80	218	236	273	260	271	259	269	335
88	281	314	330	323	358	336	363	373
96	342	362	392	408	397	400	425	427
104	393	411	414	411	419	410	399	447
112	401	440	358	395	394	432	401	407
120	412	387	391	391	368	365	385	330
128	371	354	348	322	294	315	295	315
136	282	294	284	253	272	265	239	238
144	241	234	238	214	230	213	175	192
152	197	175	160	151	144	151	126	135
160	134	144	150	104	110	113	120	103
168	94	86	85	77	79	88	74	63
176	77	68	67	62	62	62	62	60
184	56	66	43	50	60	56	38	54
192	45	42	38	48	53	43	39	29
200	39	25	39	49	46	31	42	43
208	34	25	24	26	32	34	31	31
216	18	28	25	24	30	28	28	30
224	24	27	32	22	26	22	22	22
232	25	28	26	23	32	23	21	18
240	25	22	21	18	21	28	21	26
248	16	20	20	22	20	19	30	0

SPACING = 1.101
DELTA TIME = .05
START CHANNEL = 7
END CHANNEL = 247
START COUNTS = 27.18
END COUNTS = 21.18
CONSTANT BACKGROUND = 10.59
DECAYING BACKGROUND = 16.79
DECAY CONSTANT OF BACKGROUND = .03741
NEUTRON MONITOR = 1.2209
FLOW VELOCITY =(.193)



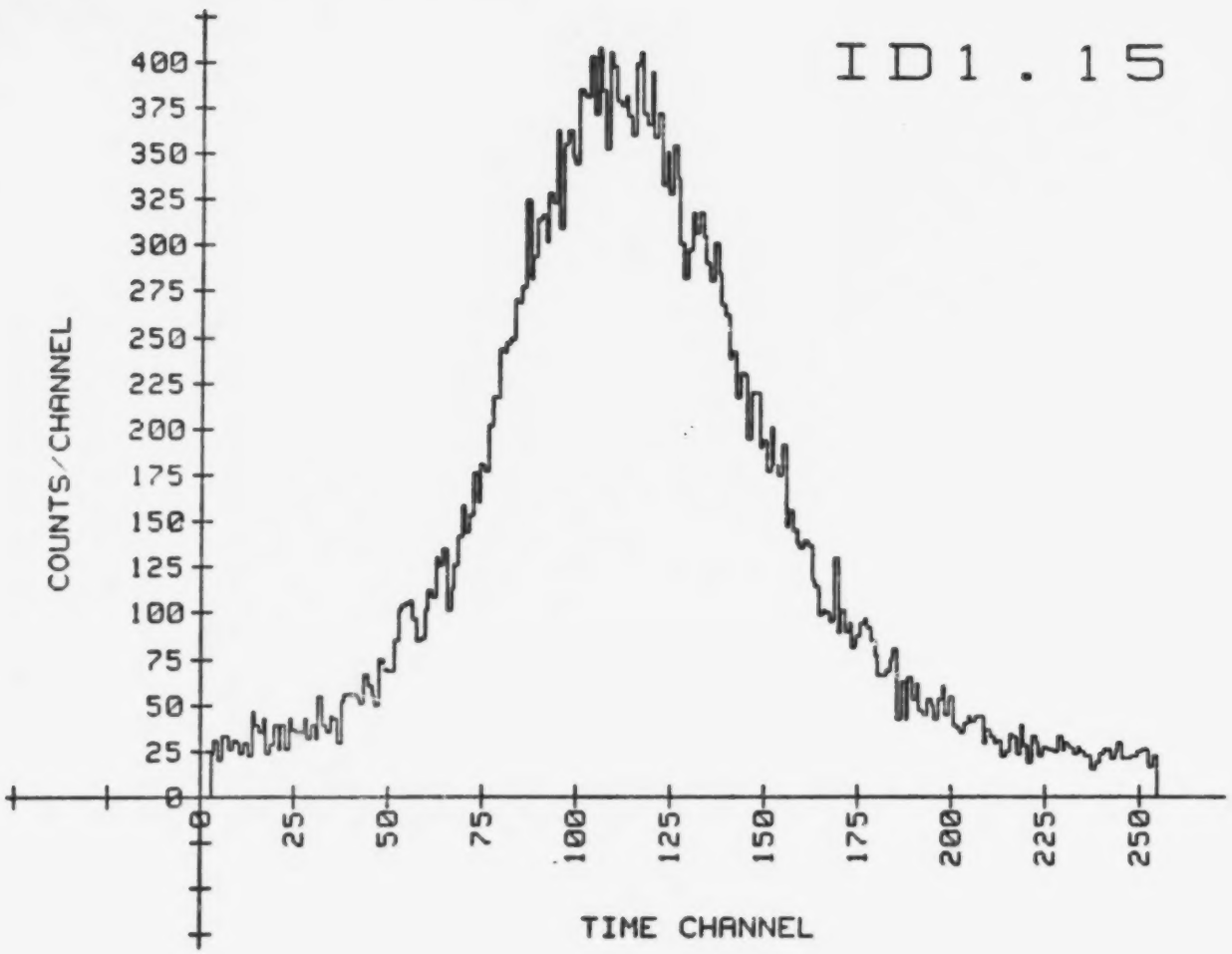
THE PEAK OF THE DISTRIBUTION IS IN TIME CHANNEL 108
THIS IS OUTSIDE OF THE SPECIFIED LIMITS, 50 - 100,
AND THE ACCURACY OF THE TEST RESULT IS THEREBY REDUCED.

PLEASE CORRECT THE LENGTH OF THE TIME CHANNELS OF THE MULTISCALER
BEFORE THE NEXT TEST.

RUN NUMBER = ID1.15

0	0	0	0	24	31	20	33	33
8	26	31	29	24	29	22	46	39
16	36	42	24	28	39	26	39	26
24	43	37	36	35	42	32	39	32
32	54	39	35	44	43	29	52	55
40	56	56	54	51	66	60	54	50
48	74	70	69	68	85	102	104	106
56	107	97	85	86	102	112	109	130
64	126	135	102	114	127	142	159	144
72	154	176	161	181	177	202	218	218
80	243	242	247	250	271	270	278	325
88	283	294	315	317	303	329	324	363
96	310	356	363	349	345	385	383	382
104	403	373	408	386	354	405	399	379
112	377	382	371	361	400	406	372	366
120	395	359	372	334	351	329	355	337
128	301	283	298	318	307	318	305	291
136	282	302	285	269	263	239	242	217
144	231	229	195	220	220	190	194	177
152	201	181	175	191	148	156	145	138
160	136	139	137	118	115	99	102	101
168	96	130	90	102	90	95	81	87
176	94	97	92	85	77	66	66	68
184	75	80	43	63	43	65	53	61
192	47	45	53	50	43	53	60	45
200	54	39	38	35	40	44	41	44
208	44	30	37	33	29	31	22	25
216	34	33	24	39	28	19	33	30
224	23	27	26	26	25	33	26	29
232	27	24	27	25	23	23	15	19
240	24	26	26	21	25	30	21	21
248	23	22	25	26	26	17	22	0

SPACING = 1.101
DELTA TIME = .05
START CHANNEL = 7
END CHANNEL = 247
START COUNTS = 25.45
END COUNTS = 24.18
CONSTANT BACKGROUND = 12.09
DECAYING BACKGROUND = 13.4
DECAY CONSTANT OF BACKGROUND = .00832
NEUTRON MONITOR = 1.19
FLOW VELOCITY =(.194)



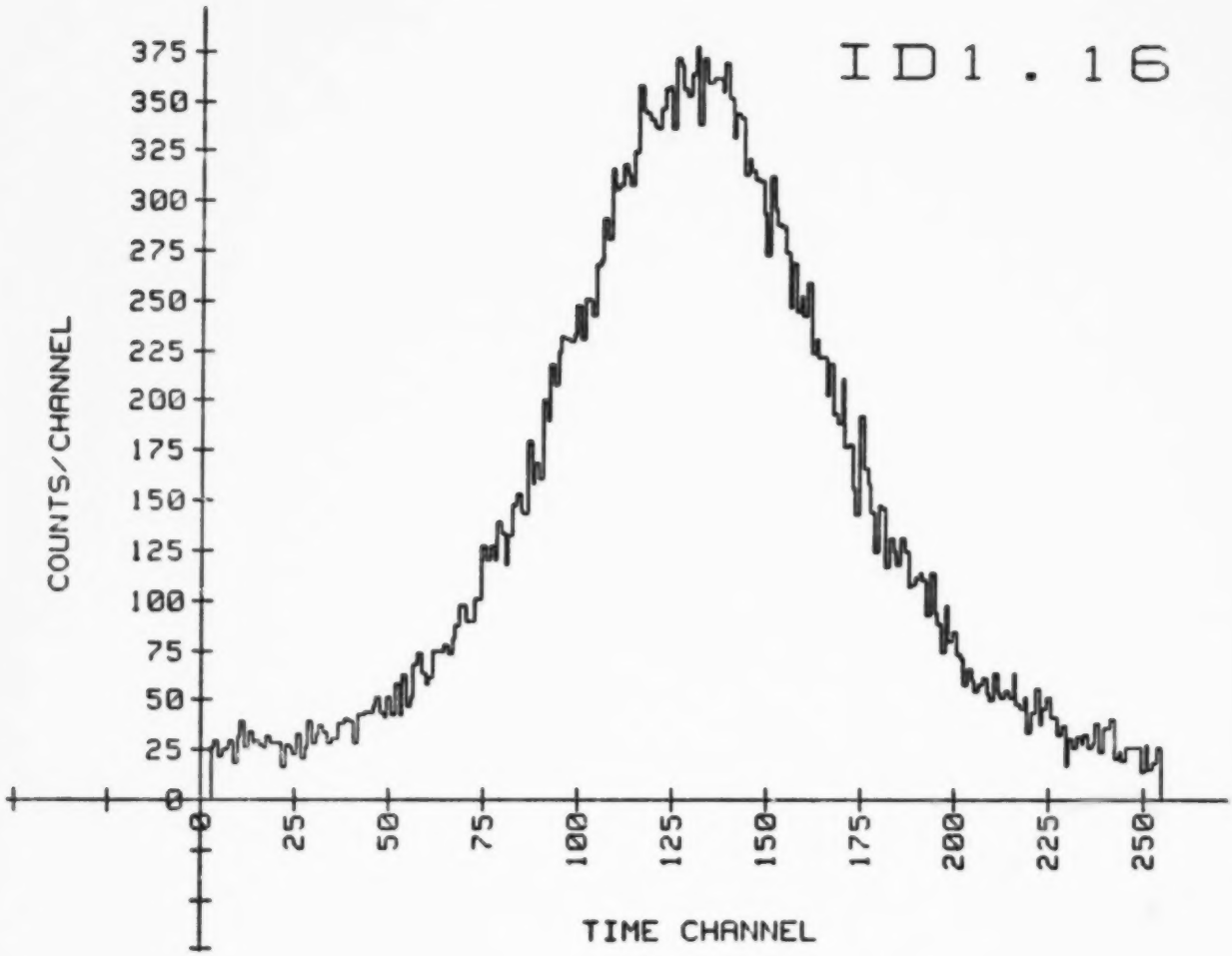
THE PEAK OF THE DISTRIBUTION IS IN TIME CHANNEL 106
THIS IS OUTSIDE OF THE SPECIFIED LIMITS, 50 - 100,
AND THE ACCURACY OF THE TEST RESULT IS THEREBY REDUCED.

PLEASE CORRECT THE LENGTH OF THE TIME CHANNELS OF THE MULTISCALER
BEFORE THE NEXT TEST.

RUN NUMBER = ID1.16

0	0	0	0	26	30	22	25	26
8	30	19	32	39	26	34	28	30
16	27	26	32	29	29	29	16	27
24	26	23	33	21	26	39	29	33
32	37	34	29	31	31	38	38	41
40	39	29	43	43	44	44	47	51
48	44	42	52	43	58	43	62	47
56	52	68	73	64	58	61	74	74
64	75	78	73	81	88	98	98	90
72	90	101	101	127	121	127	121	139
80	134	118	133	148	153	145	143	180
88	159	169	161	200	191	218	208	225
96	232	231	230	233	248	231	251	251
104	243	268	271	291	282	317	307	309
112	319	314	309	325	358	346	345	342
120	338	337	347	357	358	337	373	369
128	357	354	365	378	340	373	360	360
136	363	363	356	370	353	333	345	343
144	314	322	317	312	311	295	274	313
152	297	289	288	275	248	269	245	253
160	243	260	225	231	222	222	204	219
168	194	189	211	177	179	157	144	193
176	167	159	145	125	148	147	117	132
184	125	118	131	125	107	108	112	114
192	111	93	114	94	89	75	98	80
200	84	73	71	58	66	60	55	58
208	61	54	50	64	54	52	55	51
216	64	48	46	52	34	44	56	38
224	46	51	42	42	33	37	18	31
232	26	32	29	33	26	28	38	24
240	36	36	41	21	24	20	26	26
248	26	26	14	27	15	19	26	0

SPACING = 1.101
DELTA TIME = .05
START CHANNEL = 7
END CHANNEL = 247
START COUNTS = 25
END COUNTS = 24.18
CONSTANT BACKGROUND = 12.09
DECAYING BACKGROUND = 12.93
DECAY CONSTANT OF BACKGROUND = .00547
NEUTRON MONITOR = 1.19
FLOW VELOCITY =(.167)



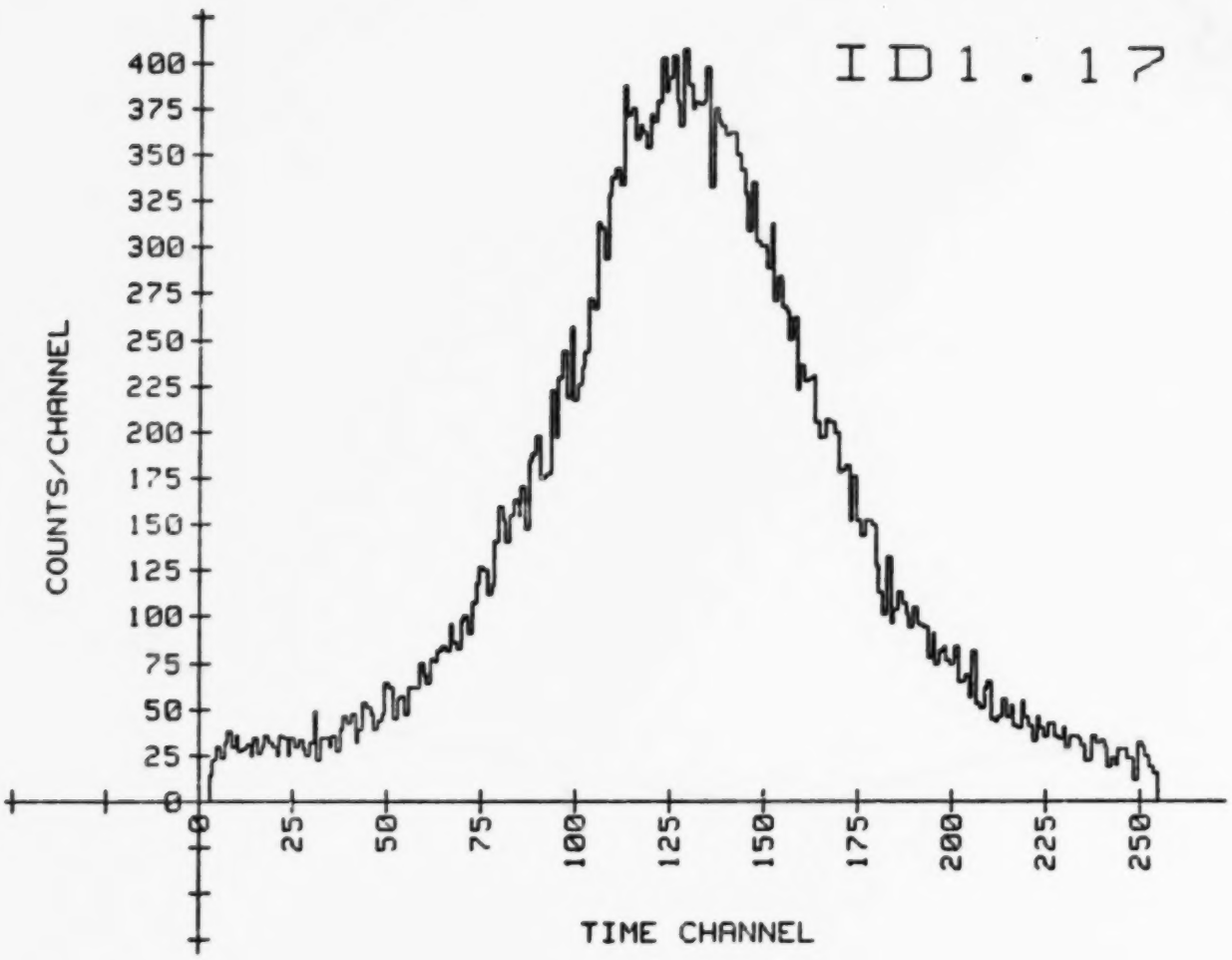
THE PEAK OF THE DISTRIBUTION IS IN TIME CHANNEL 131
THIS IS OUTSIDE OF THE SPECIFIED LIMITS, 50 - 100,
AND THE ACCURACY OF THE TEST RESULT IS THEREBY REDUCED.

PLEASE CORRECT THE LENGTH OF THE TIME CHANNELS OF THE MULTISCALER
BEFORE THE NEXT TEST.

RUN NUMBER = ID1.17

0	0	0	0	14	22	30	24	32
8	38	29	35	27	28	31	25	34
16	26	29	35	32	30	25	36	34
24	25	34	30	33	28	25	32	40
32	23	34	34	30	35	27	39	46
40	43	47	32	39	53	51	47	39
48	44	47	64	61	45	56	57	47
56	61	62	61	75	68	64	77	76
64	81	84	82	96	86	83	98	101
72	91	108	118	127	125	112	117	141
80	160	152	141	155	163	155	170	148
88	185	188	197	175	176	177	222	197
96	229	244	219	257	217	226	235	243
104	272	267	313	311	295	329	338	343
112	335	388	372	376	360	366	363	355
120	373	369	379	403	386	392	404	380
128	367	408	389	376	380	378	379	398
136	333	376	369	367	362	363	363	351
144	343	330	310	336	304	302	302	290
152	313	272	285	268	266	251	263	223
160	237	228	229	231	206	198	198	207
168	206	200	179	180	182	152	176	153
176	144	153	152	150	128	114	102	132
184	97	104	113	108	102	95	105	97
192	96	94	78	91	75	82	84	77
200	75	84	65	65	69	57	82	53
208	51	62	65	45	44	46	56	46
216	52	41	40	54	46	41	33	46
224	40	36	43	42	35	34	40	29
232	36	35	34	31	23	23	35	32
240	33	30	19	24	20	28	28	24
248	24	12	32	29	25	19	15	0

SPACING = 1.101
DELTA TIME = .05
START CHANNEL = 7
END CHANNEL = 247
START COUNTS = 25.36
END COUNTS = 24.09
CONSTANT BACKGROUND = 12.05
DECAYING BACKGROUND = 13.35
DECAY CONSTANT OF BACKGROUND = .00836
NEUTRON MONITOR = 1.1911
FLOW VELOCITY =(.169)



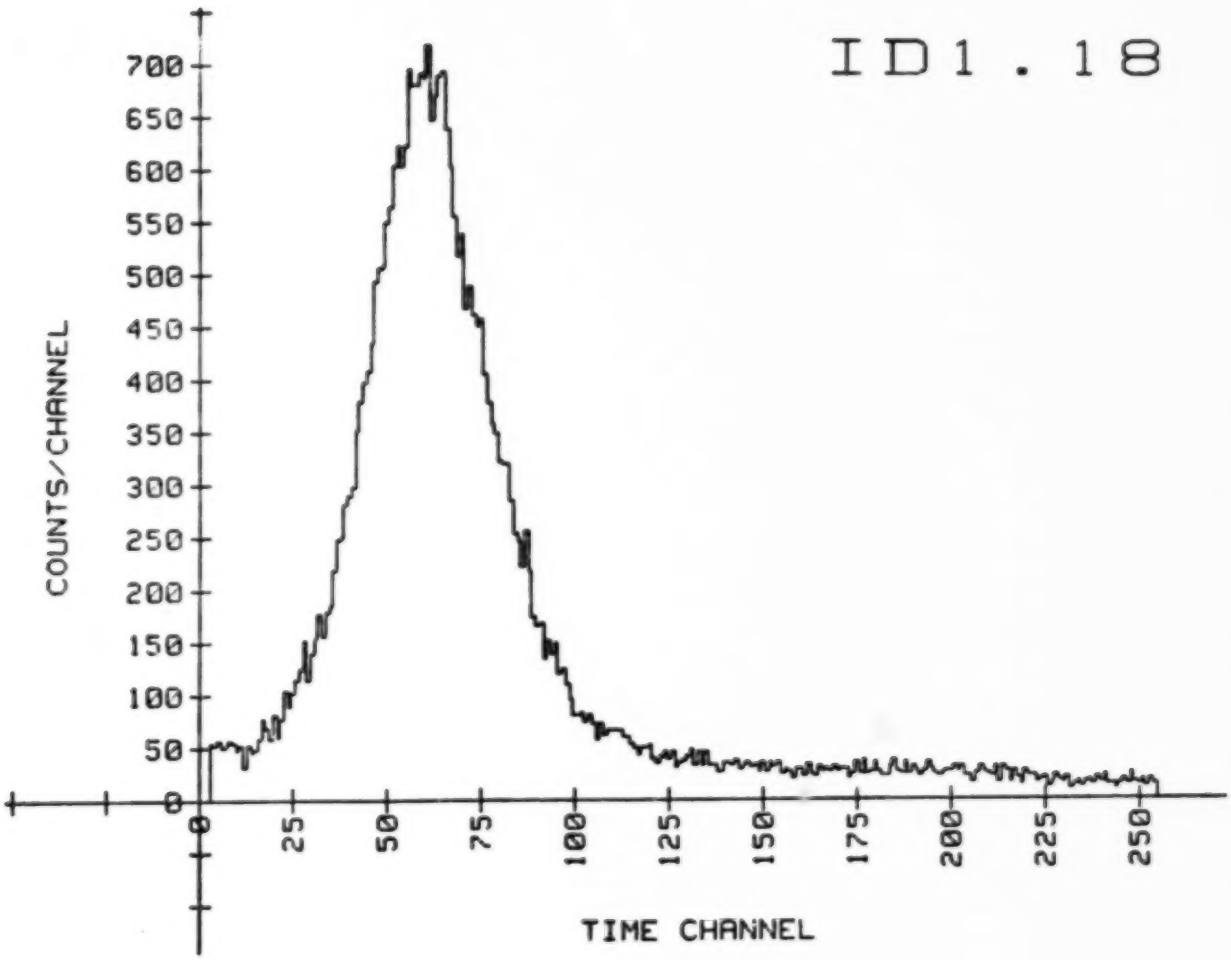
THE PEAK OF THE DISTRIBUTION IS IN TIME CHANNEL 127
THIS IS OUTSIDE OF THE SPECIFIED LIMITS, 50 - 100,
AND THE ACCURACY OF THE TEST RESULT IS THEREBY REDUCED.

PLEASE CORRECT THE LENGTH OF THE TIME CHANNELS OF THE MULTISCALER
BEFORE THE NEXT TEST.

RUN NUMBER = ID1.18

0	0	0	0	54	53	56	49	51
8	56	55	48	53	32	53	46	48
16	58	77	69	58	81	61	77	105
24	90	101	114	124	151	115	140	153
32	176	157	179	185	218	248	249	280
40	290	297	351	379	398	408	435	493
48	506	508	549	564	604	623	603	623
56	696	680	680	691	686	718	648	671
64	688	692	638	603	556	518	538	469
72	488	462	451	458	405	379	357	349
80	322	320	320	285	254	247	223	256
88	218	175	167	168	136	152	139	150
96	121	125	111	95	82	82	83	75
104	81	72	59	72	63	67	66	67
112	66	60	60	55	50	43	49	49
120	53	40	36	42	46	40	46	32
128	36	37	42	48	33	45	34	45
136	34	34	26	28	35	35	34	38
144	29	33	36	31	34	26	36	27
152	36	32	36	24	30	28	20	29
160	30	22	33	25	23	31	28	30
168	28	31	28	30	30	21	24	36
176	24	37	25	26	35	28	22	22
184	31	38	28	25	36	24	32	28
192	23	28	35	29	25	23	25	26
200	28	31	28	32	23	23	17	25
208	32	27	25	23	31	17	32	26
216	17	27	20	14	26	22	22	16
224	19	21	13	17	22	18	16	21
232	10	15	17	12	17	18	15	21
240	16	22	14	15	10	15	19	14
248	25	16	14	18	13	18	15	0

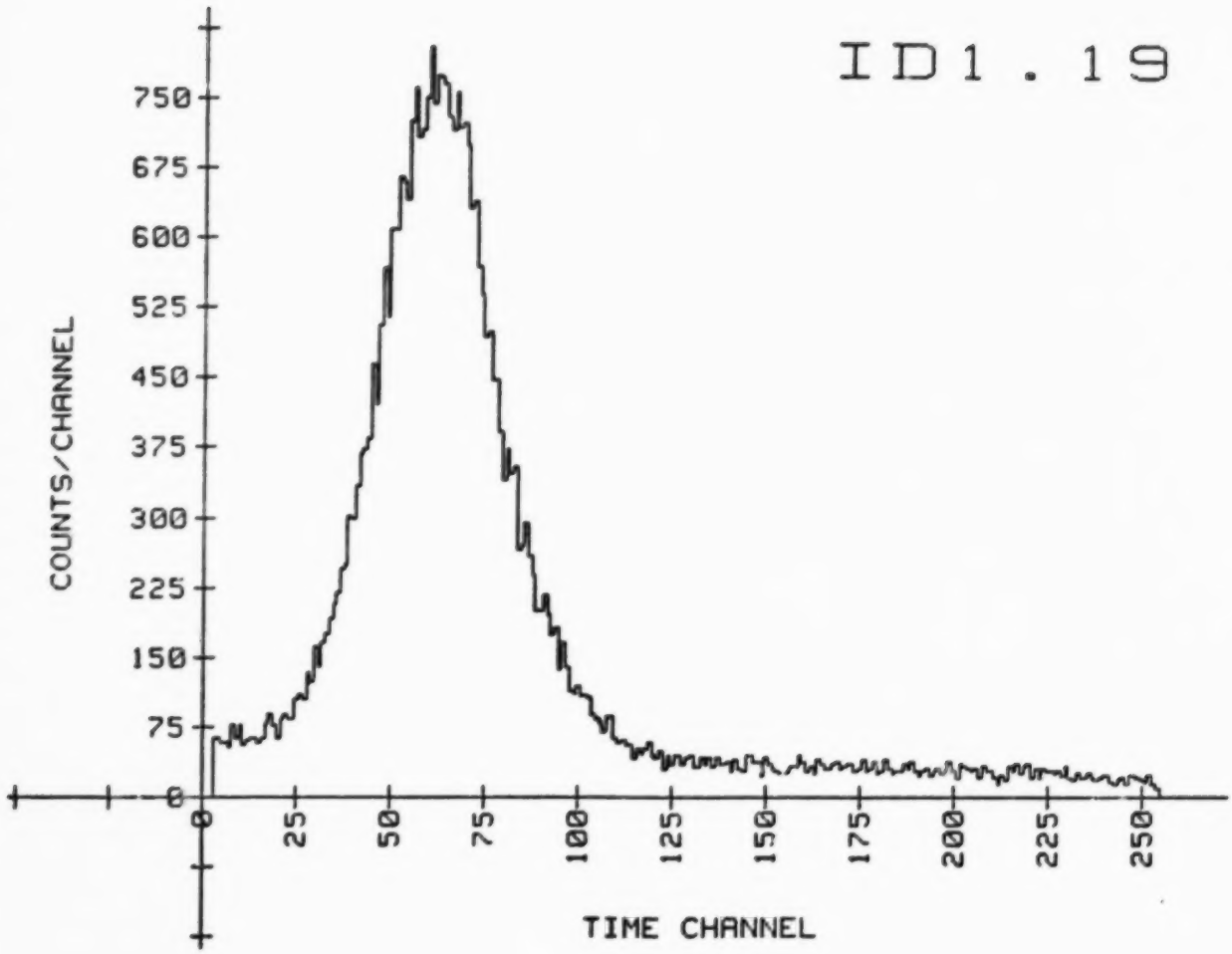
SPACING = 1.101
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 143
START COUNTS = 46.09
END COUNTS = 32.64
CONSTANT BACKGROUND = 16.05
DECAYING BACKGROUND = 30.9
DECAY CONSTANT OF BACKGROUND = .04366
NEUTRON MONITOR = 1.0735
FLOW VELOCITY = .177


ID1.18
COUNTS/CHANNEL
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

RUN NUMBER = ID1.19

0	0	0	0	64	63	59	59	54
8	76	62	77	56	61	64	62	58
16	63	79	89	78	64	84	89	84
24	83	106	110	105	133	124	160	140
32	165	175	191	208	219	246	249	301
40	298	333	368	373	385	466	422	508
48	567	517	609	610	666	662	643	726
56	762	709	717	753	806	746	775	773
64	767	730	716	757	719	724	700	634
72	639	570	540	496	501	449	448	393
80	342	374	349	355	266	270	294	260
88	238	202	200	217	197	175	183	137
96	167	139	114	112	118	110	109	107
104	89	85	80	71	86	86	62	59
112	61	57	56	43	52	46	51	59
120	45	43	48	30	45	35	44	44
128	36	43	45	33	32	41	34	41
136	33	42	36	35	37	29	39	30
144	27	45	44	38	37	24	41	34
152	30	28	25	26	27	32	32	45
160	37	27	32	26	40	36	31	30
168	36	38	31	33	35	36	28	31
176	39	29	30	38	25	29	40	30
184	25	28	28	35	30	37	29	24
192	29	31	24	29	30	25	29	37
200	29	22	36	32	31	29	31	21
208	33	28	29	22	15	24	19	32
216	28	34	25	33	35	20	31	21
224	30	28	29	25	28	24	32	20
232	18	25	20	20	26	20	19	20
240	23	23	17	15	19	21	14	24
248	23	20	19	17	24	13	9	0

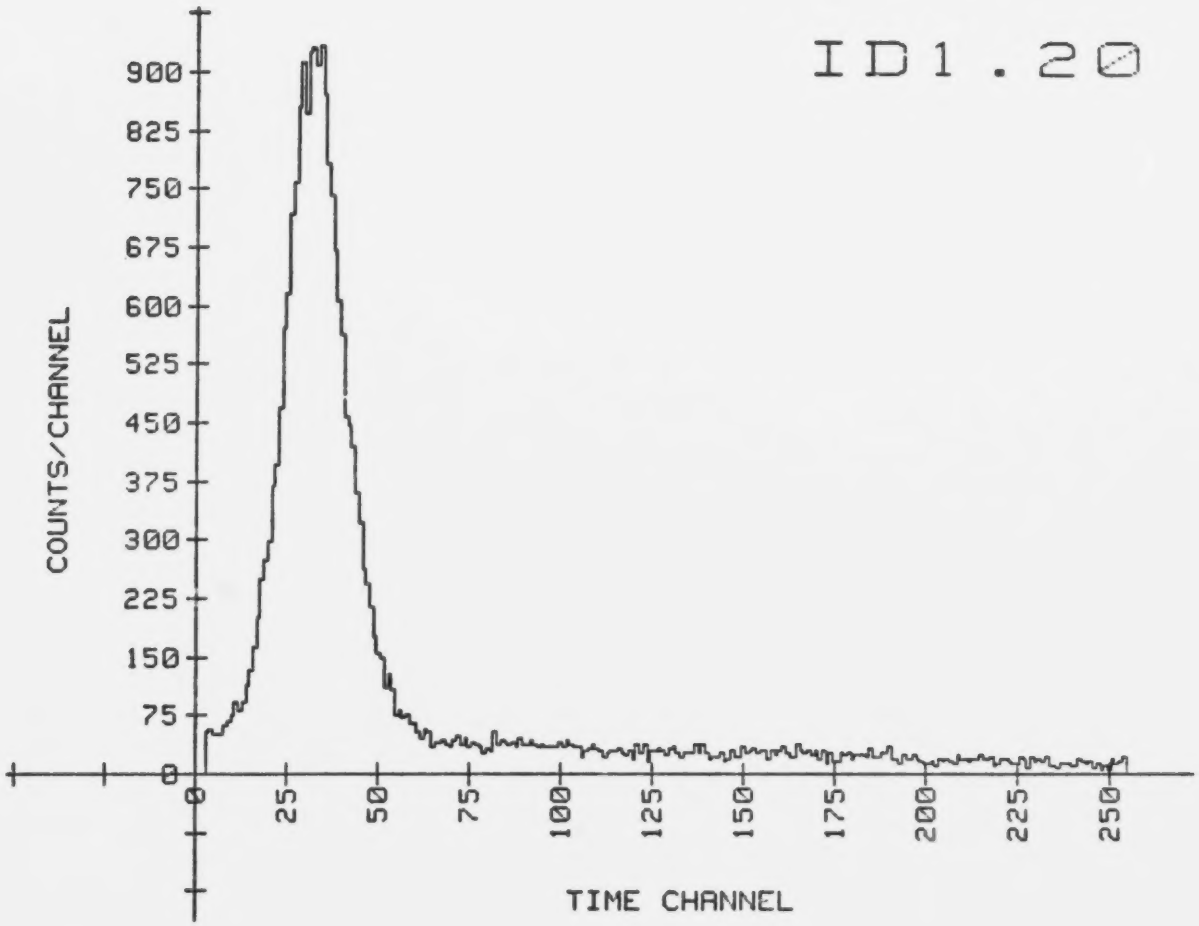
SPACING = 1.101
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 151
START COUNTS = 57.36
END COUNTS = 32.18
CONSTANT BACKGROUND = 16.09
DECAYING BACKGROUND = 43.06
DECAY CONSTANT OF BACKGROUND = .06541
NEUTRON MONITOR = 1.1294
FLOW VELOCITY = .174


ID1.19
COUNTS/CHANNEL
750
675
600
525
450
375
300
225
150
75
0
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

RUN NUMBER = ID1.20

0	0	0	0	53	57	52	51	52
8	61	67	77	91	82	93	115	134
16	162	200	248	274	298	369	395	468
24	571	615	719	758	657	914	848	926
32	933	911	935	872	783	743	672	608
40	563	458	446	420	361	323	263	244
48	213	176	155	149	112	126	109	76
56	81	73	75	65	66	54	45	56
64	54	34	41	41	42	39	35	42
72	48	39	46	34	41	38	35	26
80	33	31	54	39	43	40	38	41
88	35	45	38	39	43	38	36	38
96	35	36	34	35	41	35	43	37
104	36	35	21	31	33	37	32	31
112	22	27	30	31	32	28	24	29
120	19	37	27	37	16	30	31	32
128	30	24	32	36	26	23	27	27
136	26	39	28	38	27	20	22	22
144	26	16	18	30	21	23	34	28
152	30	32	26	29	31	20	30	24
160	29	35	27	23	22	37	31	28
168	30	25	30	20	29	13	26	16
176	16	28	24	26	19	25	25	25
184	21	32	21	22	28	27	34	20
192	20	14	25	20	19	24	19	16
200	14	14	16	11	20	17	19	15
208	13	24	20	19	16	18	18	25
216	18	18	22	11	14	20	19	16
224	13	13	21	19	7	23	15	18
232	15	22	12	12	9	14	13	14
240	11	11	18	16	14	17	7	14
248	5	11	5	19	13	15	22	0

SPACING = 1.101
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 71
START COUNTS = 58.45
END COUNTS = 40.73
CONSTANT BACKGROUND = 12.36
DECAYING BACKGROUND = 48.42
DECAY CONSTANT OF BACKGROUND = .07582
NEUTRON MONITOR = 1.0859
FLOW VELOCITY =(.345)



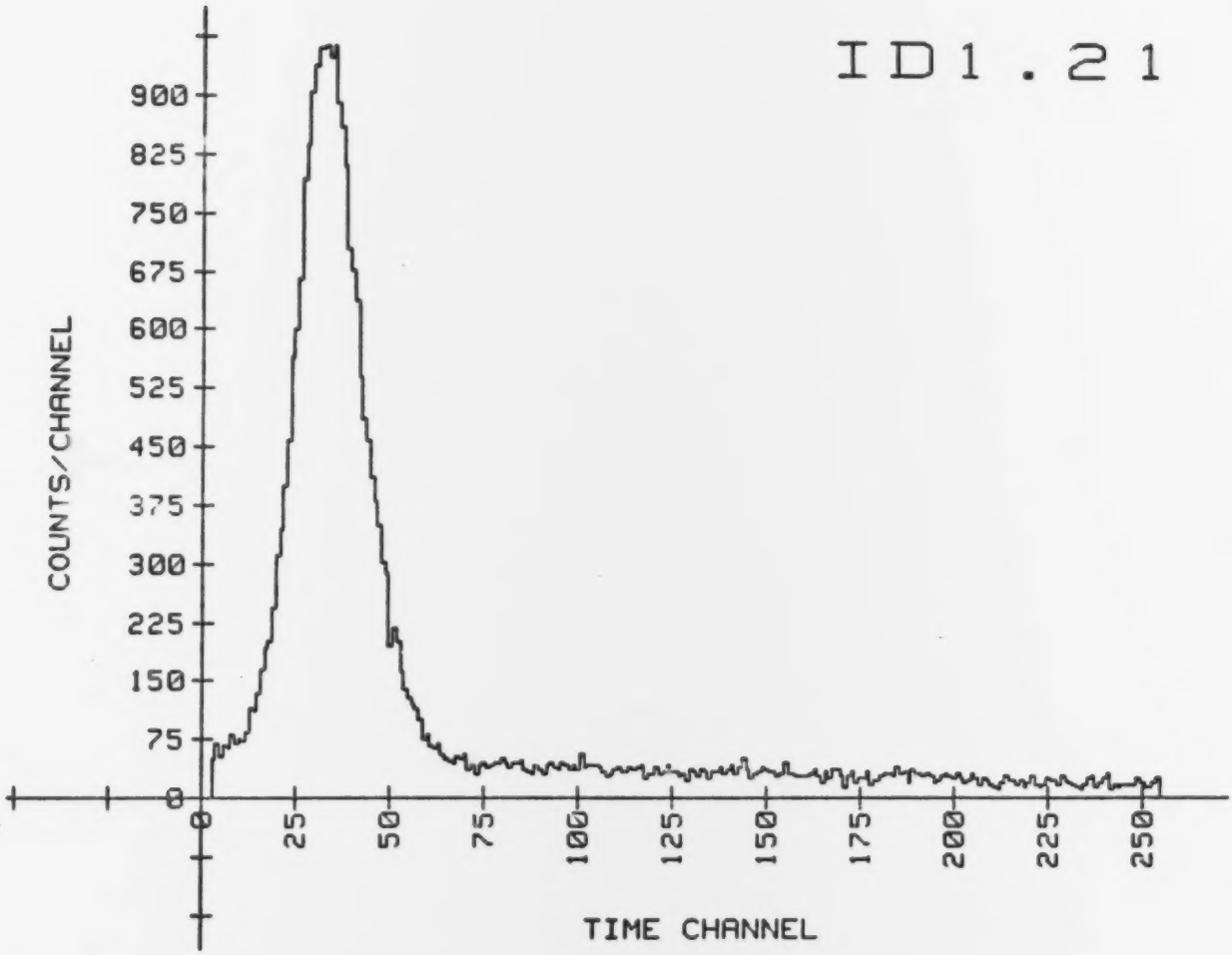
THE PEAK OF THE DISTRIBUTION IS IN TIME CHANNEL 32
THIS IS OUTSIDE OF THE SPECIFIED LIMITS, 50 - 100,
AND THE ACCURACY OF THE TEST RESULT IS THEREBY REDUCED.

PLEASE CORRECT THE LENGTH OF THE TIME CHANNELS OF THE MULTISCALER
BEFORE THE NEXT TEST.

RUN NUMBER = ID1.21

0	0	0	0	50	71	54	66	63
8	80	69	75	73	85	115	113	135
16	164	192	201	244	311	344	400	458
24	566	600	667	795	838	906	941	963
32	963	964	952	965	891	860	811	705
40	678	639	539	486	458	410	379	350
48	303	288	196	219	201	161	141	128
56	121	114	101	76	80	67	63	71
64	56	51	47	44	52	51	55	36
72	41	32	42	44	40	41	45	46
80	49	45	38	46	46	47	37	33
88	32	43	35	30	43	46	38	35
96	46	42	35	41	35	55	38	42
104	41	43	38	34	27	32	37	39
112	34	33	39	37	40	41	25	31
120	32	40	31	33	41	33	34	27
128	32	23	36	34	27	37	33	25
136	34	33	38	32	35	41	32	38
144	49	36	26	31	34	40	37	34
152	33	29	31	46	31	31	28	28
160	28	29	31	35	29	19	34	26
168	36	37	28	15	28	33	20	24
176	24	34	17	22	23	27	31	31
184	28	38	31	34	20	36	31	32
192	28	30	27	19	22	28	30	27
200	24	30	25	20	23	31	26	16
208	26	22	18	14	10	19	29	21
216	22	18	21	15	19	29	18	15
224	16	24	23	23	17	27	23	19
232	18	13	12	18	26	27	14	20
240	25	30	10	16	15	18	17	18
248	16	24	19	15	15	19	25	0

SPACING = 1.101
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 73
START COUNTS = 62.36
END COUNTS = 43.55
CONSTANT BACKGROUND = 17.45
DECAYING BACKGROUND = 47.38
DECAY CONSTANT OF BACKGROUND = .08223
NEUTRON MONITOR = 1.1719
FLOW VELOCITY =(.332)



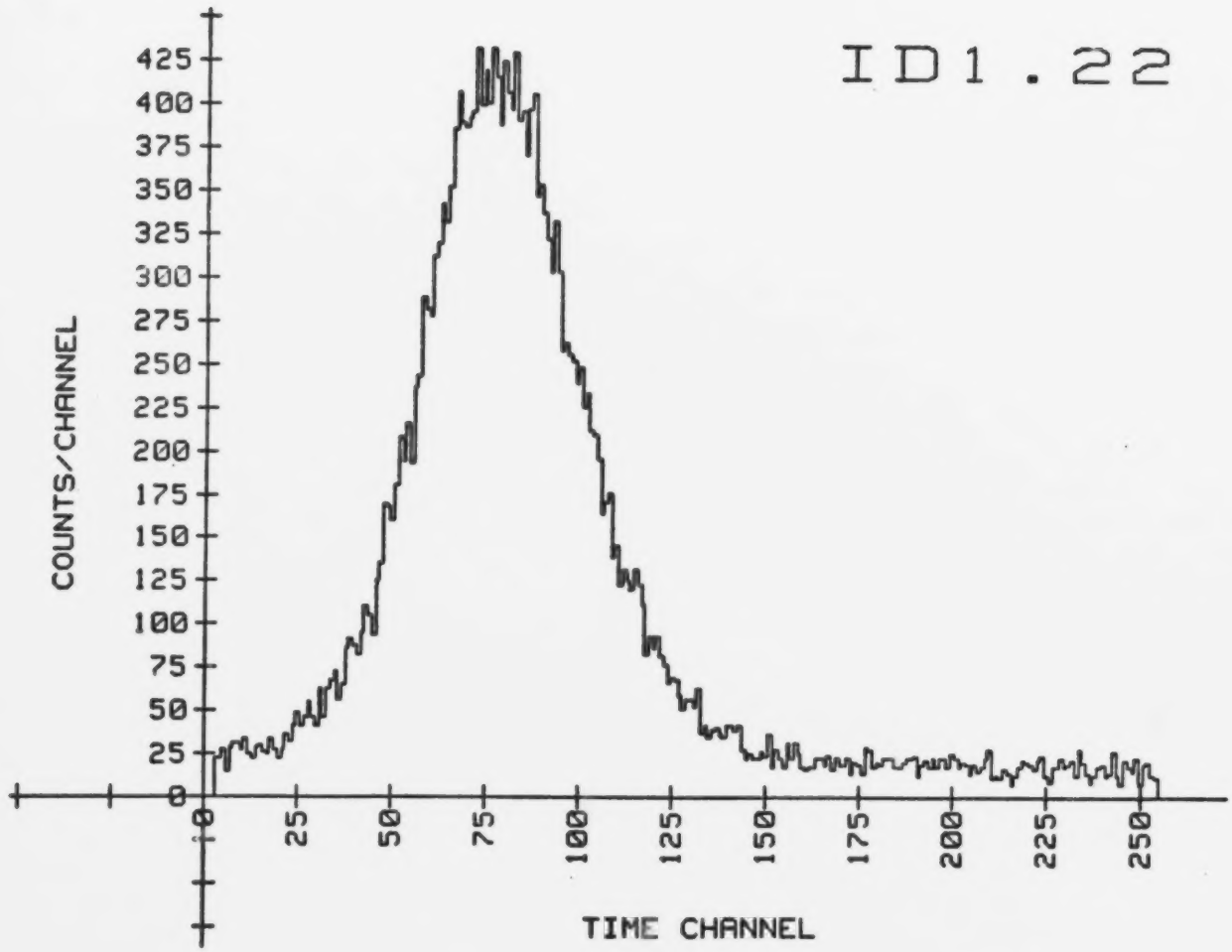
THE PEAK OF THE DISTRIBUTION IS IN TIME CHANNEL 33
THIS IS OUTSIDE OF THE SPECIFIED LIMITS, 50 - 100,
AND THE ACCURACY OF THE TEST RESULT IS THEREBY REDUCED.

PLEASE CORRECT THE LENGTH OF THE TIME CHANNELS OF THE MULTISCALER
BEFORE THE NEXT TEST.

RUN NUMBER = ID1.22

0	0	0	0	22	23	27	15	29
8	31	31	28	34	25	23	29	30
16	26	25	34	27	22	28	36	32
24	42	49	42	47	55	46	42	63
32	47	63	68	73	57	65	86	92
40	88	83	95	110	106	94	126	135
48	169	168	160	181	208	195	216	193
56	237	244	288	282	278	313	320	343
64	332	353	387	408	390	388	393	396
72	433	400	420	401	433	416	389	425
80	408	398	431	391	397	371	398	407
88	340	354	337	322	304	332	304	259
96	262	256	252	240	249	226	233	212
104	209	196	164	171	176	139	145	123
112	132	126	120	132	123	112	83	93
120	86	93	81	76	66	69	68	59
128	51	57	56	53	63	38	42	35
136	39	40	36	35	41	42	39	41
144	28	22	25	22	23	26	24	36
152	17	27	23	17	31	23	31	25
160	18	16	18	18	23	22	19	24
168	16	23	19	19	23	14	20	19
176	14	29	27	18	20	19	23	23
184	22	17	18	20	22	23	24	12
192	19	21	18	23	17	22	22	17
200	25	22	17	20	19	14	19	15
208	18	22	27	11	12	11	16	14
216	8	13	18	21	20	19	16	21
224	24	12	9	17	17	23	17	19
232	21	13	28	20	14	9	13	18
240	19	13	14	26	12	8	21	17
248	15	22	8	19	20	13	11	0

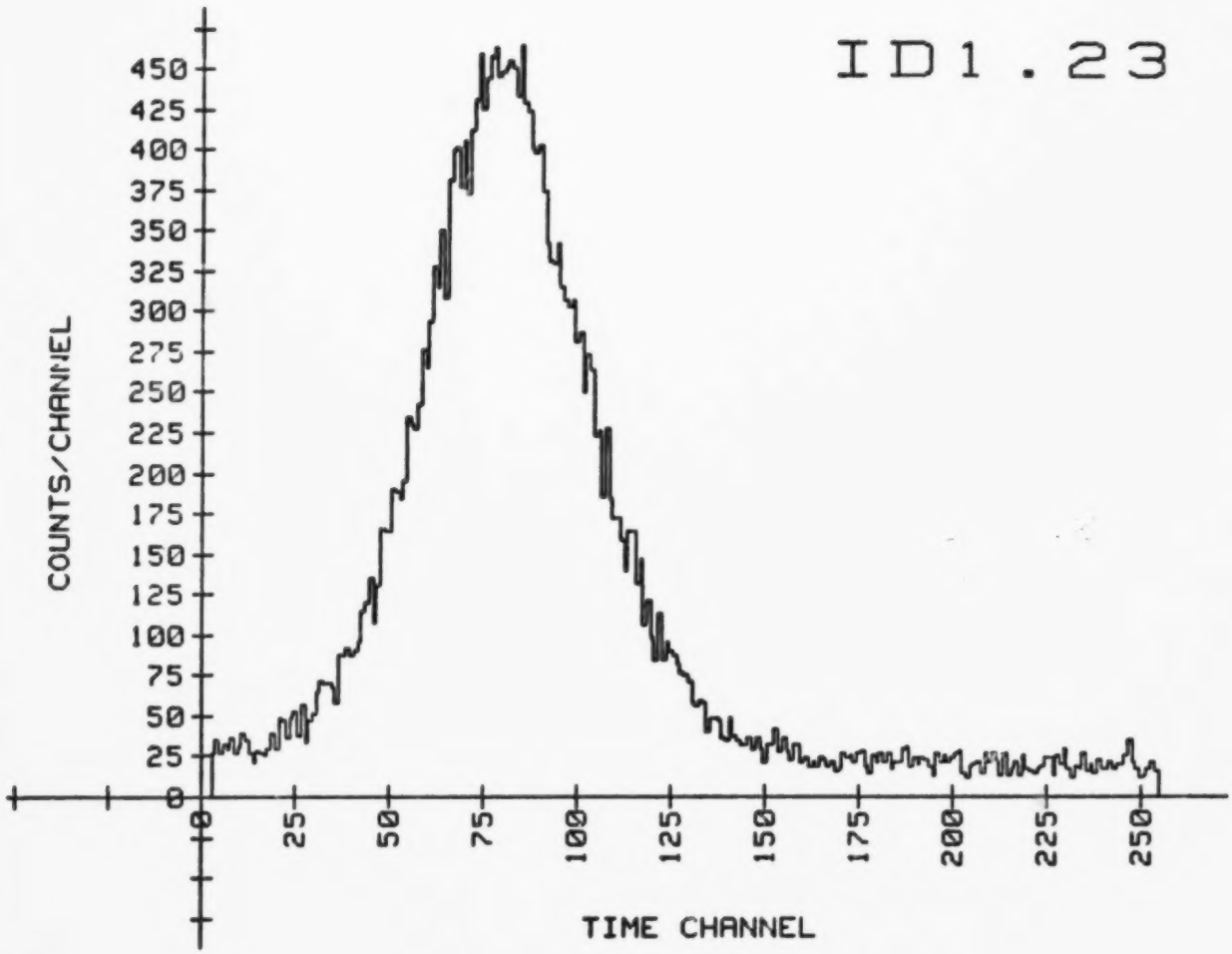
SPACING = 1.101
DELTA TIME = .05
START CHANNEL = 7
END CHANNEL = 183
START COUNTS = 24.09
END COUNTS = 20.82
CONSTANT BACKGROUND = 10.41
DECAYING BACKGROUND = 13.82
DECAY CONSTANT OF BACKGROUND = .03104
NEUTRON MONITOR = 1.0624
FLOW VELOCITY = .283


ID1.22
COUNTS/CHANNEL
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

RUN NUMBER = ID1.23

0	0	0	0	27	35	27	32	30
8	36	27	31	39	35	27	21	28
16	27	25	30	39	30	49	47	36
24	48	52	38	56	34	47	51	65
32	71	70	70	67	58	87	88	91
40	87	90	95	115	120	135	108	131
48	166	165	164	190	189	185	196	235
56	230	228	242	276	266	294	328	315
64	351	308	382	400	402	377	406	373
72	412	431	460	426	445	458	464	446
80	449	451	455	451	434	465	430	424
88	402	399	403	374	342	332	330	342
96	315	307	303	307	281	287	251	273
104	264	224	226	186	228	184	172	172
112	159	140	164	165	132	147	107	121
120	98	85	113	85	96	90	88	82
128	77	76	72	58	57	59	58	40
136	48	48	47	36	35	49	38	35
144	32	32	36	30	36	29	21	33
152	32	42	28	36	28	23	32	33
160	22	24	19	22	19	24	23	19
168	22	16	18	27	24	26	22	27
176	28	19	15	26	21	27	22	27
184	17	22	22	30	31	19	24	20
192	24	23	19	14	27	21	26	21
200	24	27	28	15	12	19	20	21
208	15	27	21	27	23	13	27	13
216	17	22	14	26	17	16	15	17
224	19	24	24	13	25	20	29	17
232	12	19	17	27	16	20	15	23
240	18	17	21	17	20	20	25	35
248	22	17	12	14	17	21	16	0

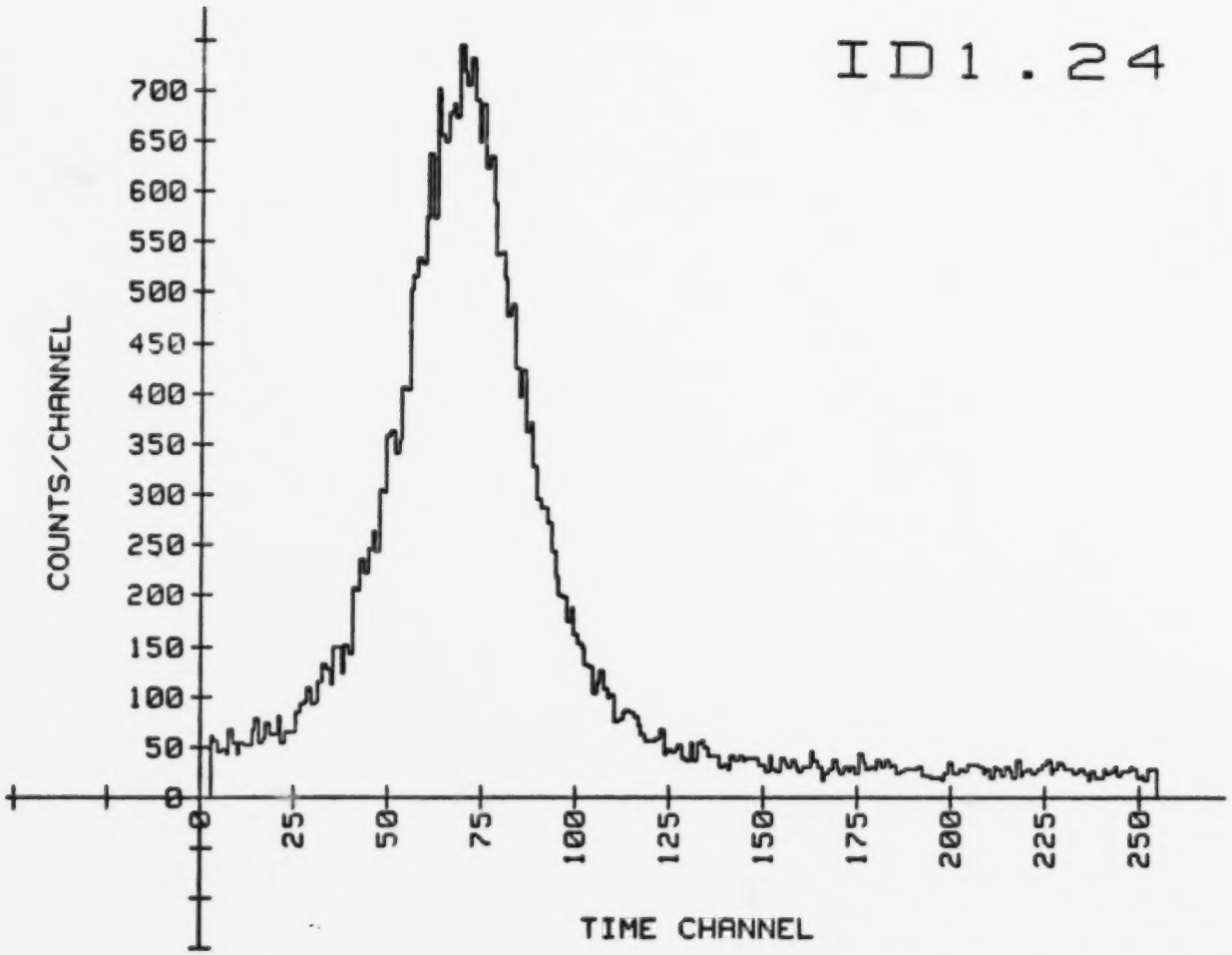
SPACING = 1.101
DELTA TIME = .05
START CHANNEL = 7
END CHANNEL = 193
START COUNTS = 29
END COUNTS = 22.55
CONSTANT BACKGROUND = 11.28
DECAYING BACKGROUND = 18
DECAY CONSTANT OF BACKGROUND = .04866
NEUTRON MONITOR = 1.1454
FLOW VELOCITY = .275


ID1.23
COUNTS/CHANNEL
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

RUN NUMBER = ID1.24

0	0	0	0	61	57	46	48	44
8	67	55	44	53	52	51	66	78
16	54	59	74	62	63	80	55	65
24	65	65	84	92	94	108	92	95
32	115	132	127	113	148	149	122	151
40	142	208	206	236	223	247	263	245
48	304	302	358	362	341	355	405	483
56	504	515	533	528	574	636	574	702
64	657	650	678	687	673	745	718	707
72	733	692	650	686	624	635	590	537
80	540	514	478	488	426	398	424	363
88	371	329	295	287	287	272	243	219
96	200	198	175	188	161	153	148	132
104	129	104	115	126	107	99	101	76
112	78	84	86	85	79	71	63	57
120	56	57	58	67	43	48	45	48
128	52	39	37	55	37	53	56	50
136	41	41	40	30	33	29	42	36
144	42	36	39	39	38	33	33	26
152	40	29	25	38	34	30	37	31
160	25	31	30	45	36	31	18	23
168	28	36	28	23	30	26	31	24
176	44	35	29	31	28	37	31	37
184	31	32	24	26	28	27	29	29
192	30	22	22	19	20	19	18	24
200	34	23	24	29	25	32	33	33
208	30	23	28	19	30	28	21	30
216	25	20	36	22	26	28	24	26
224	28	32	36	24	27	34	32	29
232	27	24	26	28	23	18	25	20
240	19	27	23	25	31	21	25	26
248	30	28	19	21	17	29	29	0

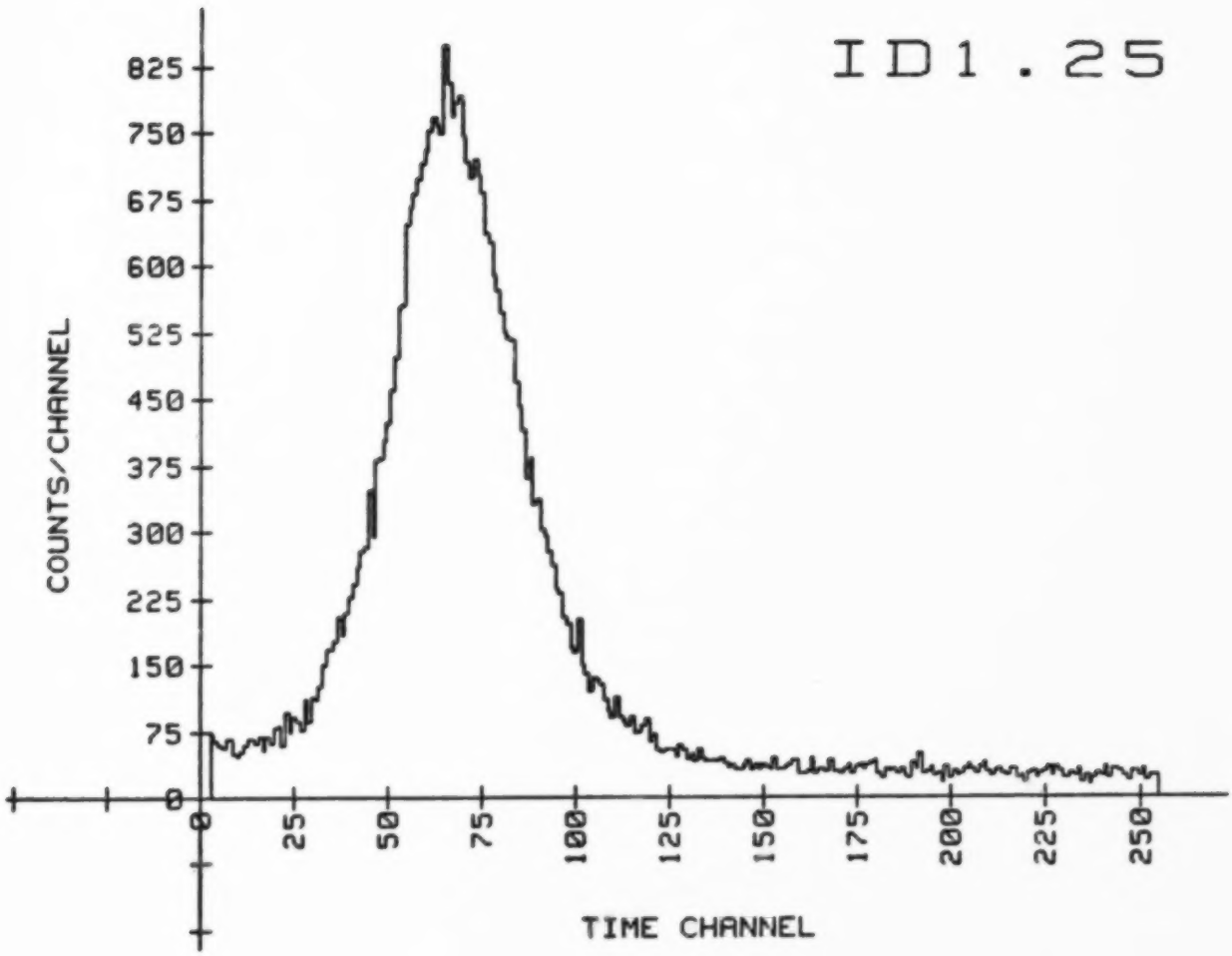
SPACING = 1.101
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 161
START COUNTS = 47.91
END COUNTS = 31.64
CONSTANT BACKGROUND = 15.82
DECAYING BACKGROUND = 33.06
DECAY CONSTANT OF BACKGROUND = .04593
NEUTRON MONITOR = 1.1532
FLOW VELOCITY = .156


ID1.24
COUNTS/CHANNEL
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

RUN NUMBER = ID1.25

0	0	0	0	72	64	58	57	67
8	66	50	47	51	59	66	67	61
16	70	53	69	61	79	80	58	95
24	74	90	86	77	110	87	114	111
32	125	149	167	168	177	204	185	210
40	227	242	262	279	283	347	295	381
48	383	404	423	459	497	553	556	648
56	666	682	698	715	731	752	767	761
64	751	949	806	771	785	793	749	719
72	702	720	703	684	637	628	590	574
80	549	526	520	516	470	444	415	362
88	383	332	336	303	296	277	263	236
96	231	204	197	170	164	201	151	140
104	120	136	134	129	111	99	90	113
112	92	86	82	91	75	75	80	88
120	64	71	53	52	53	54	53	46
128	59	55	45	50	41	54	44	42
136	43	41	42	45	39	35	37	32
144	33	38	41	33	38	33	36	35
152	33	44	32	32	35	36	42	41
160	28	28	29	45	28	31	33	30
168	43	29	29	28	31	36	27	35
176	36	31	36	39	43	28	23	33
184	29	33	26	32	25	22	40	33
192	50	28	30	34	24	26	18	35
200	23	30	25	27	31	37	33	27
208	35	39	30	25	30	32	28	25
216	33	32	21	24	17	26	29	22
224	28	30	34	24	35	29	23	21
232	26	24	31	17	24	15	23	27
240	25	34	21	33	32	30	25	19
248	29	29	25	32	20	24	25	0

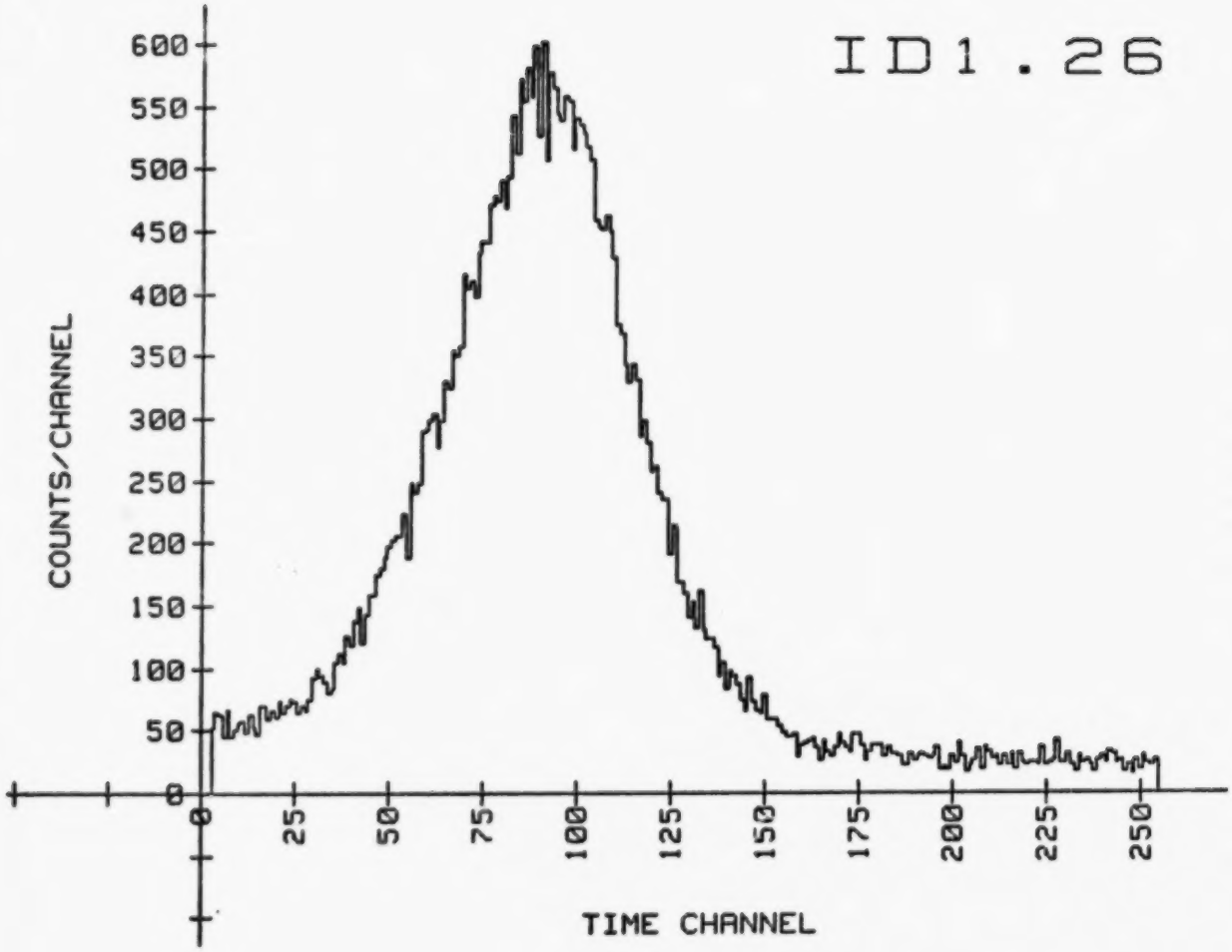
SPACING = 1.101
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 153
START COUNTS = 53.73
END COUNTS = 35.95
CONSTANT BACKGROUND = 17.98
DECAYING BACKGROUND = 36.86
DECAY CONSTANT OF BACKGROUND = .04711
NEUTRON MONITOR = 1.1896
FLOW VELOCITY = .160


ID1.25
825
750
675
600
525
450
375
300
225
150
75
0
COUNTS/CHANNEL
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

RUN NUMBER = ID1.26

0	0	0	0	53	64	62	46	66
8	46	50	55	57	48	63	53	47
16	69	70	59	66	61	74	65	70
24	75	74	65	69	67	75	92	100
32	95	89	80	83	105	112	105	125
40	118	138	148	121	143	159	158	175
48	180	189	197	203	206	206	224	189
56	247	241	248	289	292	298	304	278
64	298	329	324	354	351	357	415	405
72	410	397	432	442	442	471	478	474
80	491	469	494	543	513	573	554	581
88	559	598	527	602	507	578	565	545
96	539	559	555	516	541	535	528	518
104	508	458	453	451	462	450	429	375
112	368	343	329	343	331	286	299	281
120	259	262	241	235	236	192	215	170
128	170	161	142	154	133	163	131	123
136	124	117	95	104	83	97	95	87
144	75	67	92	73	67	64	78	60
152	59	59	54	49	46	46	47	30
160	38	40	41	43	36	27	41	33
168	29	36	47	40	37	34	47	47
176	38	27	33	39	38	38	29	37
184	31	31	30	22	23	32	26	30
192	31	30	28	29	37	19	21	20
200	30	24	40	30	17	22	27	35
208	28	36	33	28	29	23	30	23
216	32	20	31	25	22	24	24	22
224	36	23	24	27	41	25	24	31
232	23	18	30	24	26	23	17	27
240	29	24	33	31	25	27	17	22
248	16	26	20	29	24	23	27	0

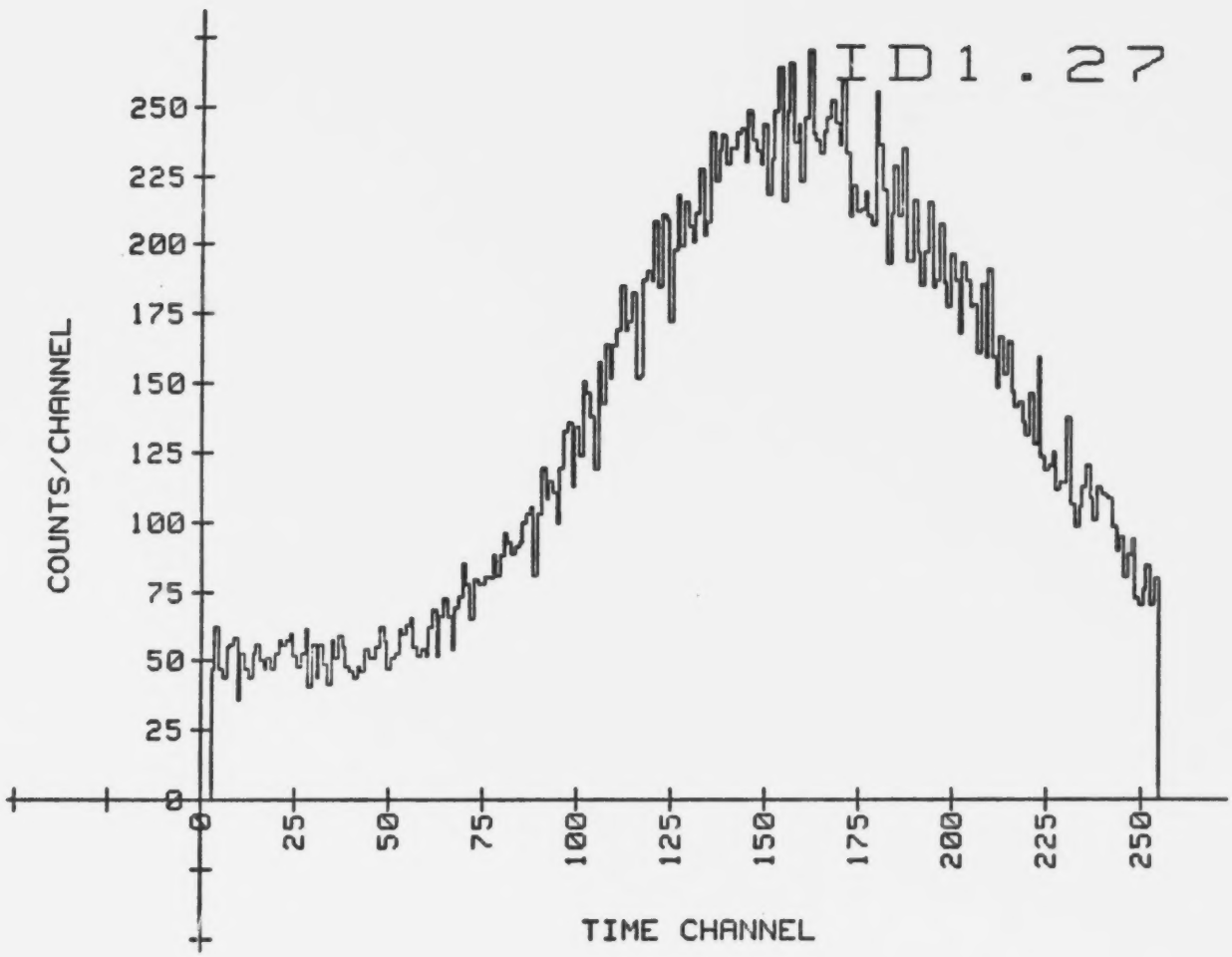
SPACING = 1.101
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 216
START COUNTS = 49.73
END COUNTS = 26.09
CONSTANT BACKGROUND = 13.05
DECAYING BACKGROUND = 37.88
DECAY CONSTANT OF BACKGROUND = .04948
NEUTRON MONITOR = 1.1482
FLOW VELOCITY = .120


ID1.26
COUNTS/CHANNEL
600
550
500
450
400
350
300
250
200
150
100
50
0
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

RUN NUMBER = ID1.27

0	0	0	0	47	62	47	44	55
8	56	58	36	53	47	44	53	56
16	50	47	51	47	53	57	56	57
24	60	52	48	53	61	41	56	44
32	56	49	42	57	51	59	55	48
40	46	44	48	46	54	51	51	55
48	62	57	47	51	53	61	60	63
56	65	55	52	54	52	62	68	52
64	66	72	66	54	69	73	85	78
72	65	79	78	78	80	80	88	81
80	88	96	93	89	91	93	100	103
88	105	81	103	119	108	115	111	100
96	119	133	136	113	134	124	151	147
104	138	119	158	143	164	152	164	170
112	185	170	173	183	152	153	188	191
120	188	209	185	211	210	173	199	218
128	200	216	207	202	212	228	204	209
136	241	224	235	240	230	236	236	241
144	243	231	249	239	235	230	244	219
152	232	249	265	217	249	266	238	244
160	224	247	271	241	239	234	242	247
168	253	245	237	260	234	211	222	213
176	214	220	211	208	256	237	221	194
184	212	229	211	236	195	195	217	198
192	186	198	216	185	188	208	187	178
200	197	188	169	194	188	178	179	162
208	186	160	192	160	149	167	154	166
216	148	142	144	137	132	147	129	160
224	124	119	121	126	112	115	115	138
232	107	99	106	113	121	109	101	113
240	111	110	109	99	90	95	81	89
248	94	73	71	76	85	71	80	0

SPACING = 1.101
DELTA TIME = .1
START CHANNEL = 7
END CHANNEL = 247
START COUNTS = 45.91
END COUNTS = 87.45
CONSTANT BACKGROUND = 43.73
DECAYING BACKGROUND = 2.01
DECAY CONSTANT OF BACKGROUND = -.12494
NEUTRON MONITOR = 1.1368
FLOW VELOCITY =(.067)



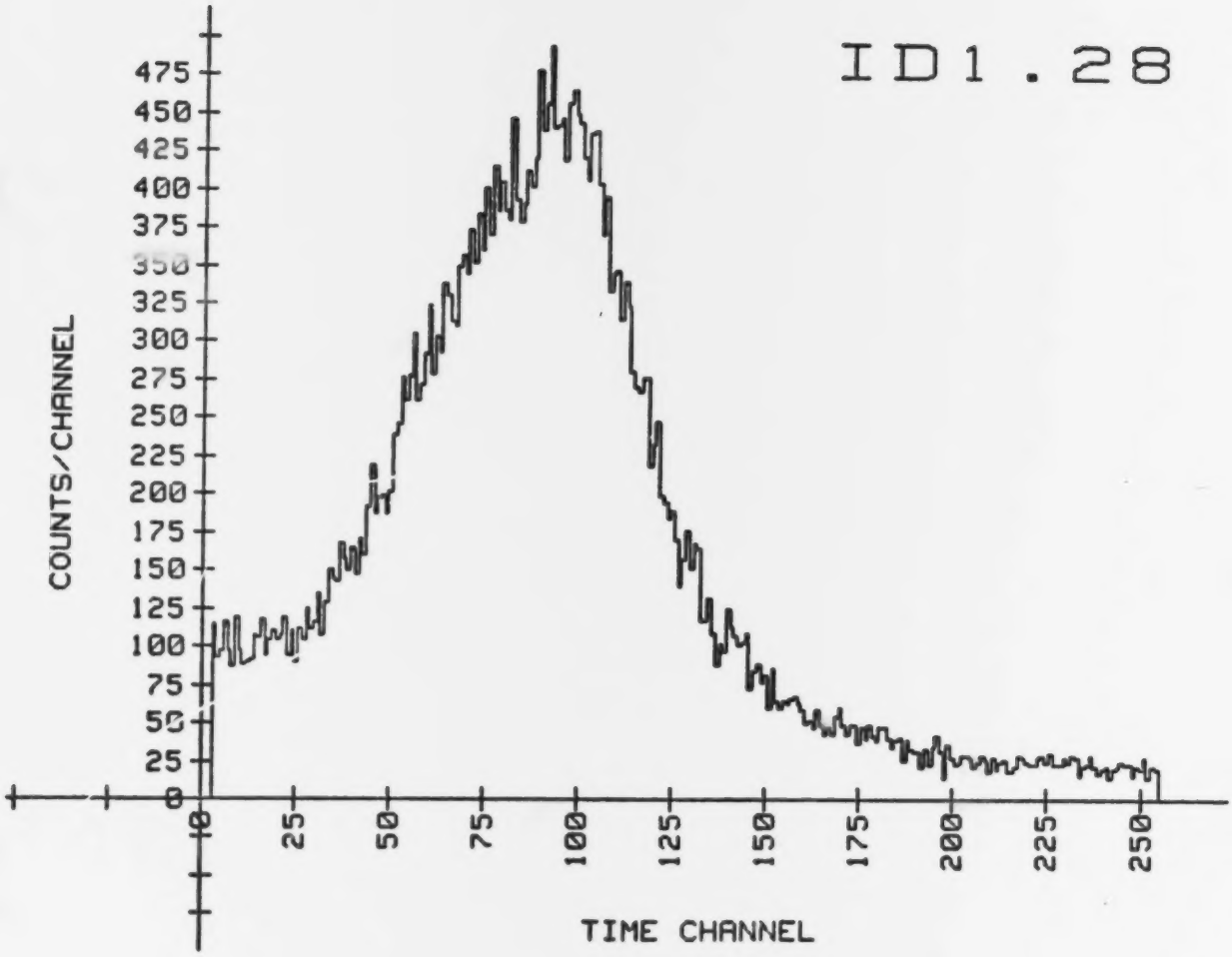
THE PEAK OF THE DISTRIBUTION IS IN TIME CHANNEL 166
THIS IS OUTSIDE OF THE SPECIFIED LIMITS, 50 - 100,
AND THE ACCURACY OF THE TEST RESULT IS THEREBY REDUCED.

PLEASE CORRECT THE LENGTH OF THE TIME CHANNELS OF THE MULTISCALER
BEFORE THE NEXT TEST.

RUN NUMBER = ID1.28

0	0	0	0	114	93	97	116	97
8	88	119	97	89	90	92	107	106
16	117	95	104	110	104	107	119	94
24	110	90	112	105	124	112	116	134
32	107	129	151	145	143	167	158	150
40	165	147	171	161	192	219	188	197
48	199	187	202	239	246	277	262	278
56	305	262	272	292	324	279	303	293
64	338	331	313	310	349	357	345	374
72	352	383	361	401	371	415	387	405
80	386	381	447	393	379	391	412	403
88	421	478	440	456	494	441	442	447
96	420	456	465	450	444	421	406	437
104	438	404	371	395	334	345	347	315
112	339	323	280	270	268	276	277	219
120	233	247	199	195	184	189	171	141
128	158	176	152	168	165	118	117	131
136	109	89	102	97	125	113	107	102
144	103	109	73	84	89	78	82	60
152	86	65	60	64	63	66	67	63
160	59	50	52	47	59	48	43	47
168	43	55	60	48	43	48	49	37
176	47	40	49	42	39	47	47	40
184	34	38	40	26	38	33	32	32
192	22	33	23	35	42	32	15	36
200	27	23	24	28	28	27	22	24
208	29	26	19	27	20	24	26	18
216	18	22	28	27	25	23	23	27
224	28	24	30	23	23	23	27	24
232	29	27	16	22	23	28	21	17
240	20	21	14	20	22	25	23	23
248	16	21	20	27	14	21	20	0

SPACING = 1.101
DELTA TIME = .2
START CHANNEL = 7
END CHANNEL = 226
START COUNTS = 90.91
END COUNTS = 25
CONSTANT BACKGROUND = 12.5
DECAYING BACKGROUND = 82.8
DECAY CONSTANT OF BACKGROUND = .04192
NEUTRON MONITOR = 1.2027
FLOW VELOCITY = .055


ID1.28
COUNTS/CHANNEL
475
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

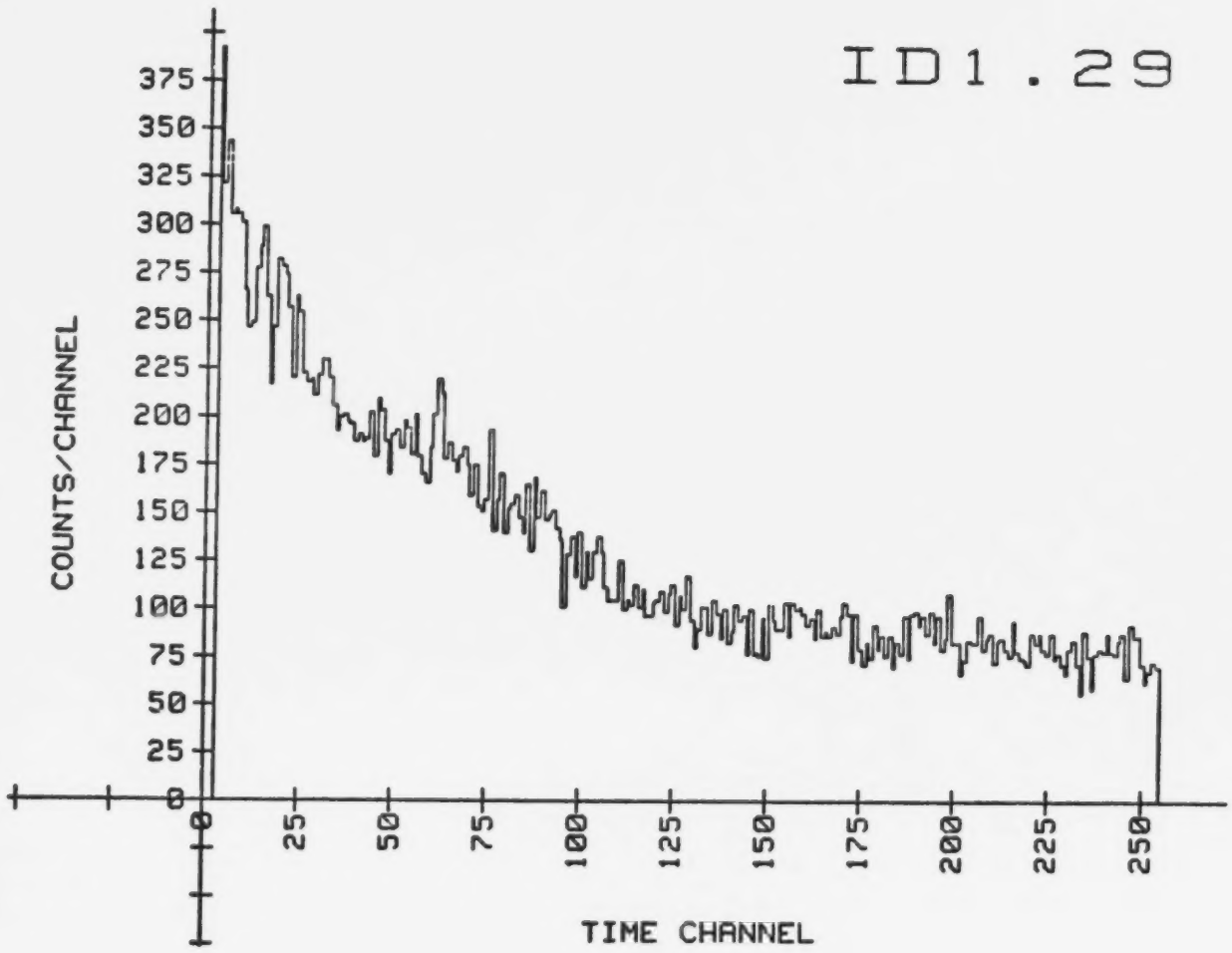
RUN NUMBER = ID1.29

0	0	0	0	392	321	343	306	308
8	306	301	266	247	249	277	288	299
16	262	217	247	282	278	274	257	220
24	262	255	223	218	219	211	221	230
32	229	220	206	193	200	201	198	196
40	188	191	187	189	202	180	209	203
48	187	170	191	193	184	198	194	181
56	201	180	170	166	184	201	219	212
64	178	186	177	172	180	184	175	159
72	175	153	151	157	193	141	157	170
80	140	152	154	159	148	140	165	131
88	160	148	161	146	149	151	142	136
96	101	128	138	117	140	111	130	116
104	129	137	129	111	105	105	104	125
112	100	105	102	113	101	110	97	97
120	103	105	109	99	108	112	92	107
128	100	117	94	81	90	101	101	88
136	105	98	85	100	83	89	102	94
144	97	77	100	77	76	95	75	102
152	94	90	90	103	86	103	100	101
160	90	92	95	85	100	86	89	86
168	91	88	96	103	98	74	98	79
176	71	83	75	92	80	86	76	86
184	70	83	77	97	75	98	99	92
192	97	88	99	83	96	79	85	108
200	83	83	67	74	84	83	83	96
208	79	85	87	73	84	85	79	76
216	94	78	75	74	72	87	83	87
224	79	77	88	75	77	71	67	79
232	84	71	57	89	76	59	77	79
240	78	88	78	77	84	88	65	92
248	86	86	72	63	68	73	70	0

SPACING = 1.101
DELTA TIME = .2
START CHANNEL = 24
END CHANNEL = 30
START COUNTS = 245.36
END COUNTS = 78.19
CONSTANT BACKGROUND = 77.41
DECAYING BACKGROUND = 267.87
DECAY CONSTANT OF BACKGROUND = .1289
NEUTRON MONITOR = 1.1943
FLOW VELOCITY = .000

START CHANNEL = 24
PEAK CHANNEL = 26
END CHANNEL = 30
NUMBER OF COUNTS IN THE VALLEY PRECEDING THE 'PEAK' = 245
NUMBER OF COUNTS AT THE 'PEAK' = 235

USING THE STANDARD DATA EVALUATION TECHNIQUE,
NO SIGNIFICANT PEAK WAS DISCOVERED OVER THE BACKGROUND LEVEL.
THEREFORE, THE FLOW VELOCITY IN THE DOWNCOMER IS ASSUMED TO BE <.03 M/SEC.


ID1.29
COUNTS/CHANNEL
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
0
25
50
75
100
125
150
175
200
225
250
TIME CHANNEL

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